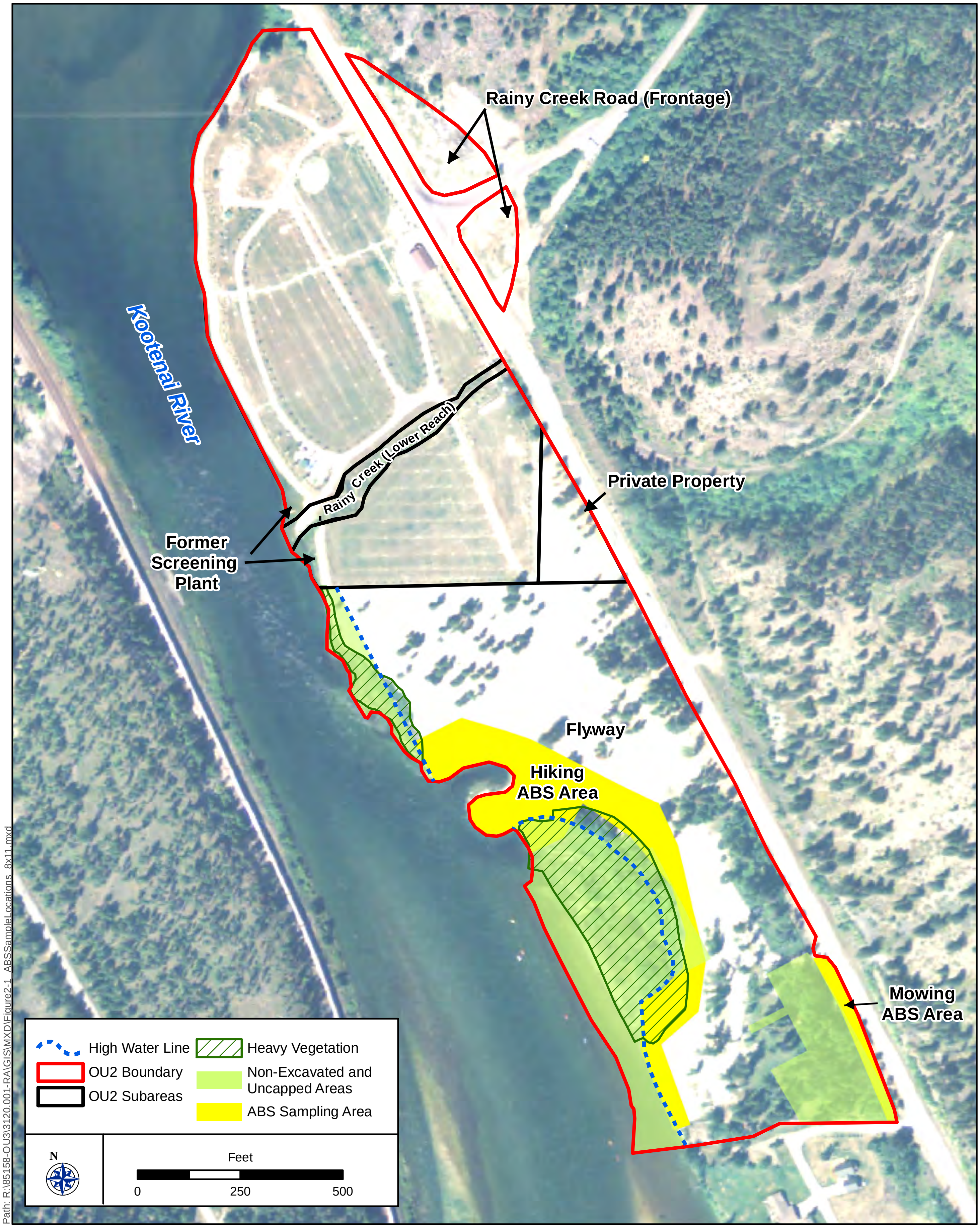


CDM Smith

OU2 ABS
Sampling Areas

FIGURE 6-5

Path: R:\85158-OU3\3120.001-RA\GIS\MXD\Fig8-1_PhaseIII_ABSarea.mxd

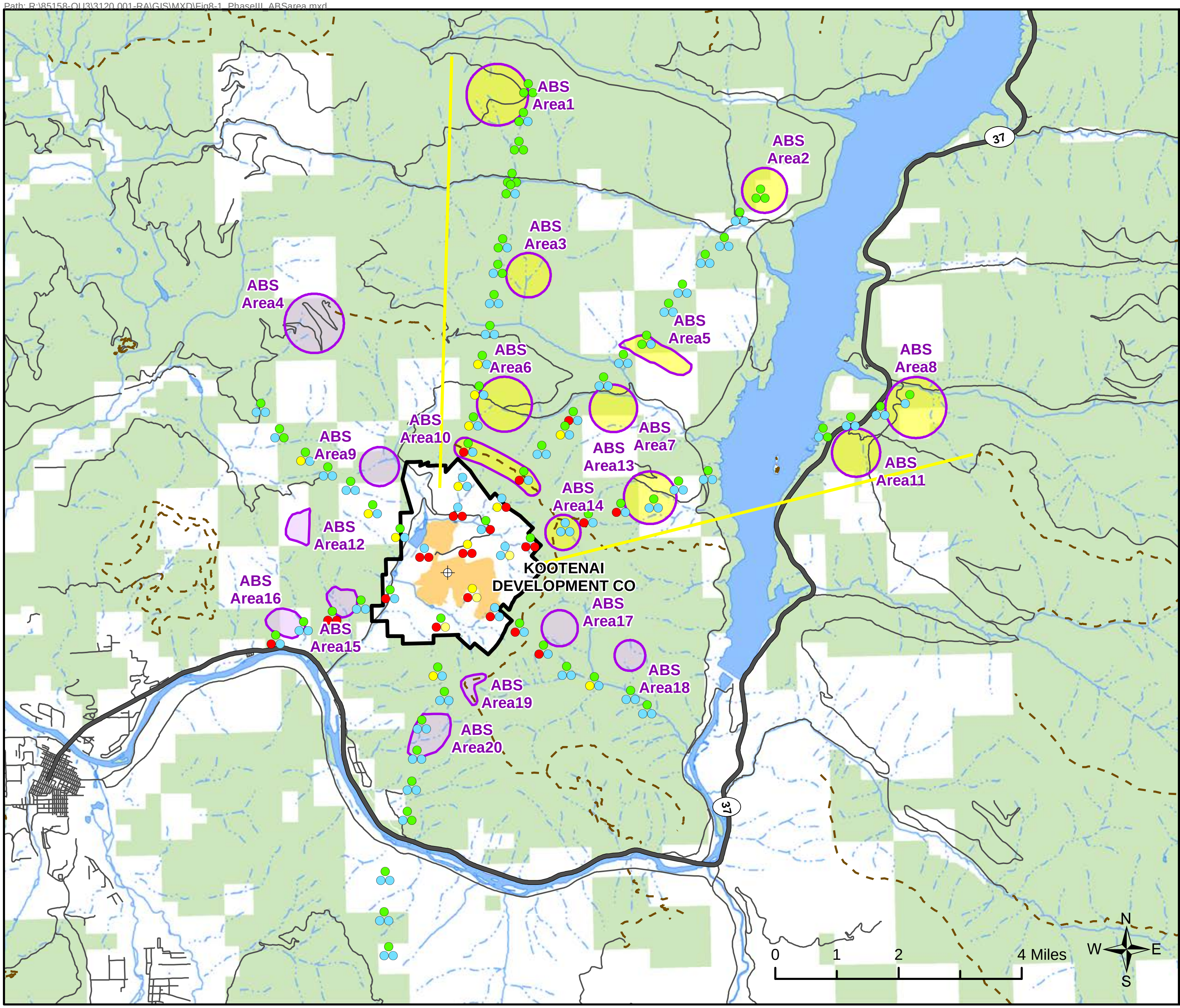
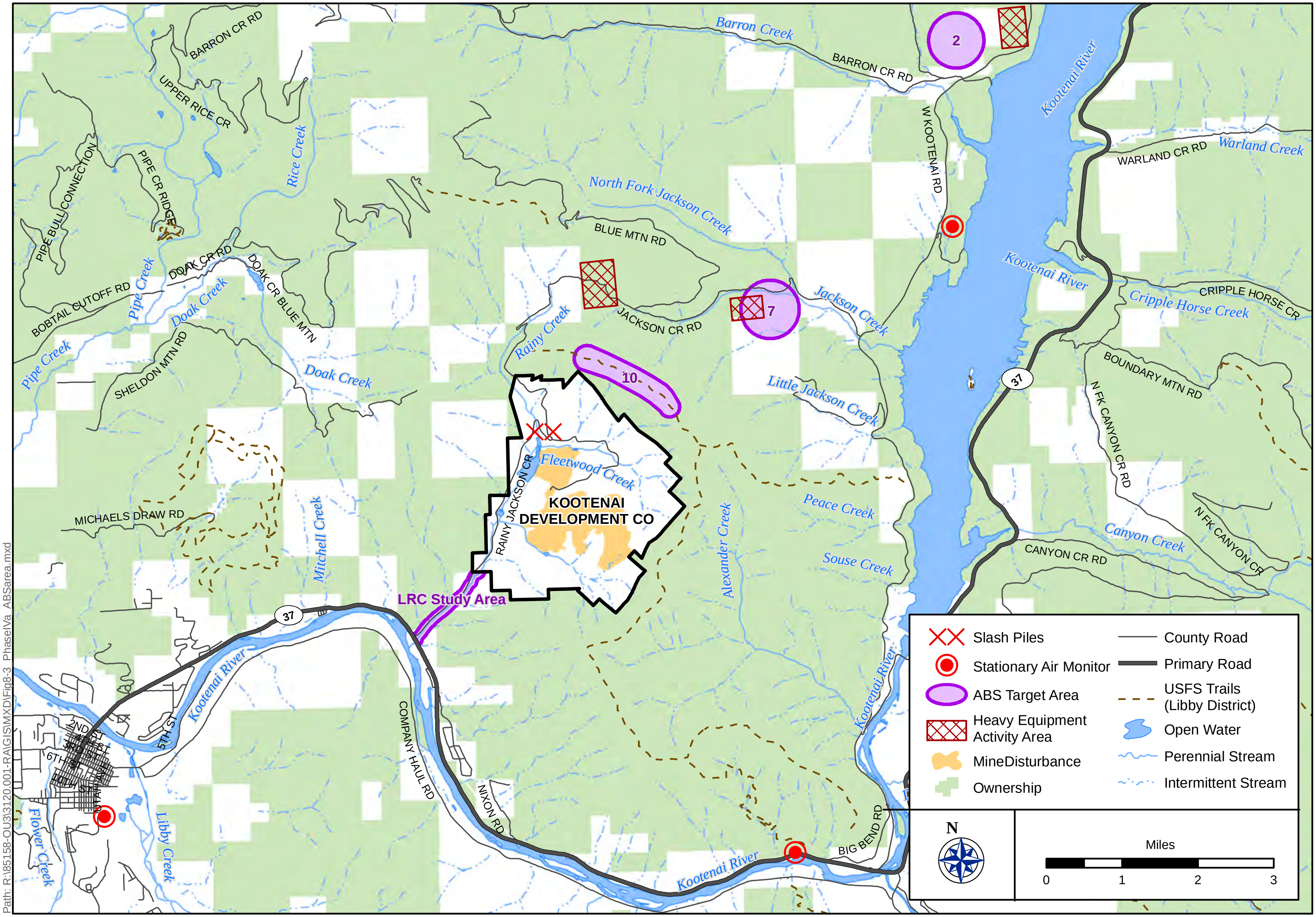


Figure 6-6

OU3 ABS Locations, Phase III

CDM Smith

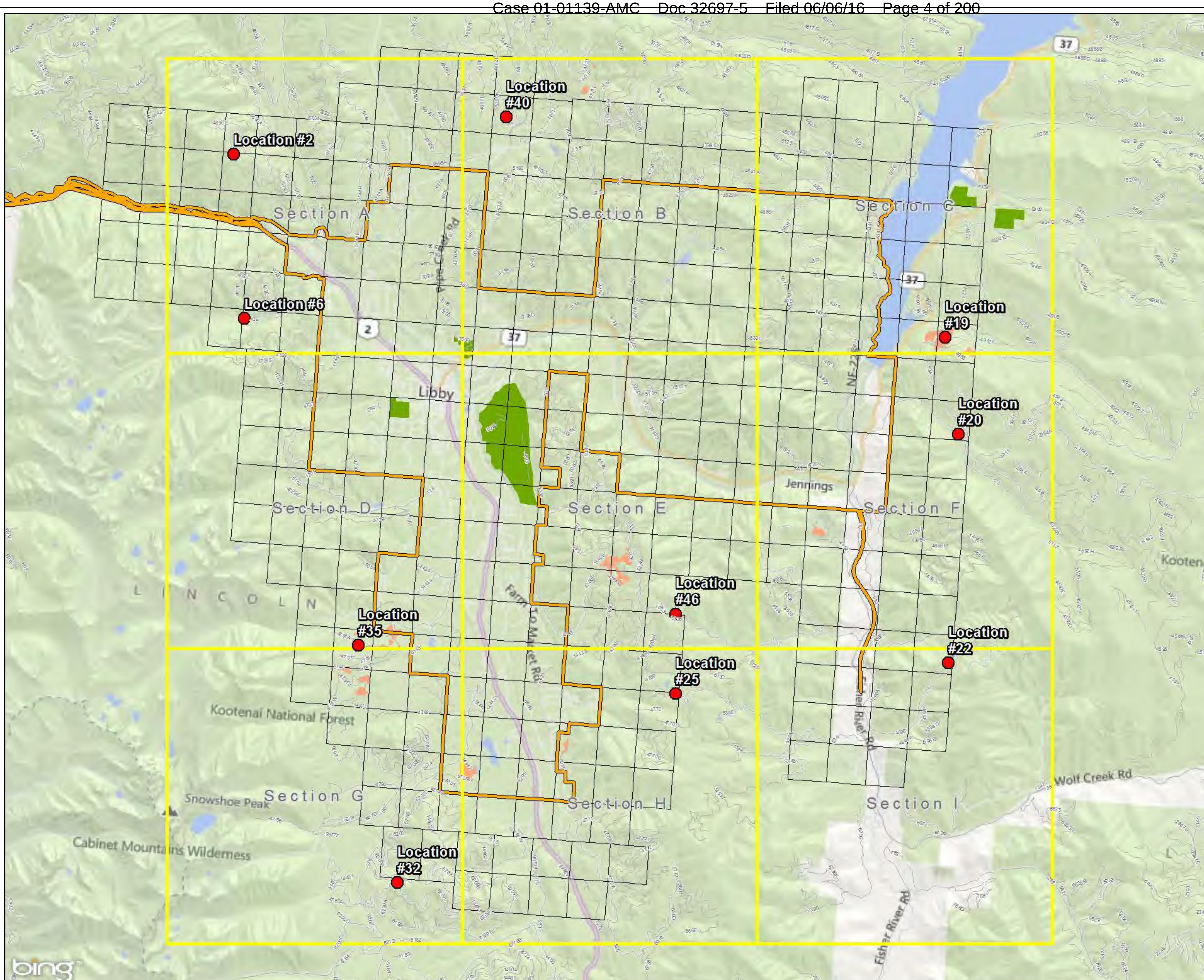


Path: R:\85158-OU3\3120.001-RA\GIS\MXD\Fig8-3_PhaseIVa_ABSarea.mxd

CDM Smith

OU3 ABS Sample Locations Phase IV, Part A

FIGURE 6-7



Legend

- Sampling Locations
- Forest Service Roads
- Libby Asbestos NPL Boundary
- Two Mile Buffer Along the NPL Boundary
- DNRC Timber Sales
- DNRC Precommercial Tree Thinning
- Detailed Map Index

* See Appendix C for Detailed Maps

Miles

0 1.25 2.5 5

1 inch = 2.424579 miles

Data Sources:
NPL Boundary - U.S. EPA Region 8 (2011);
Timber Sales and Precommercial Tree Thinning - MT DNRC (2011);
Base - Microsoft Bing (2011)

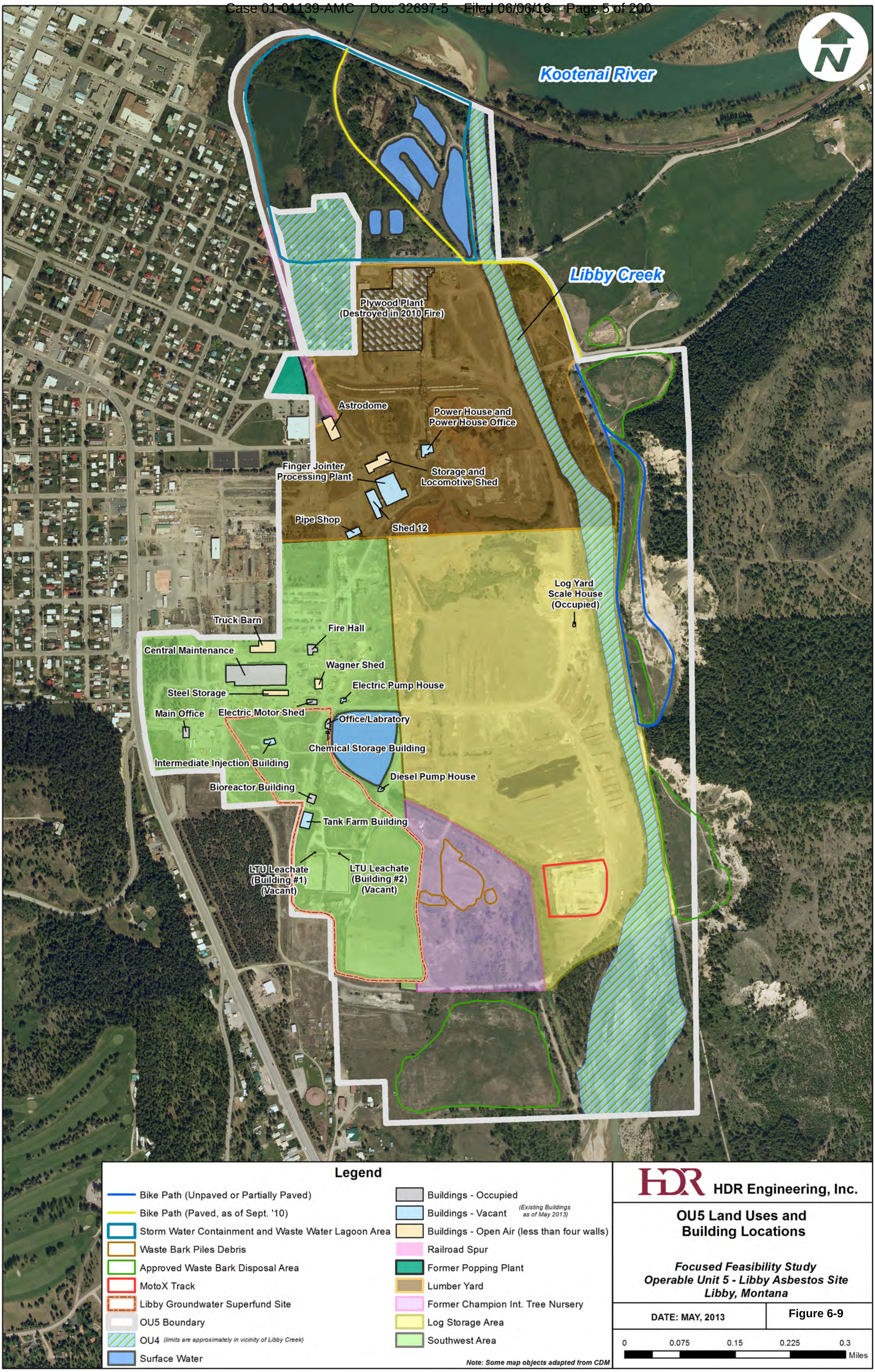
For Official Use Only

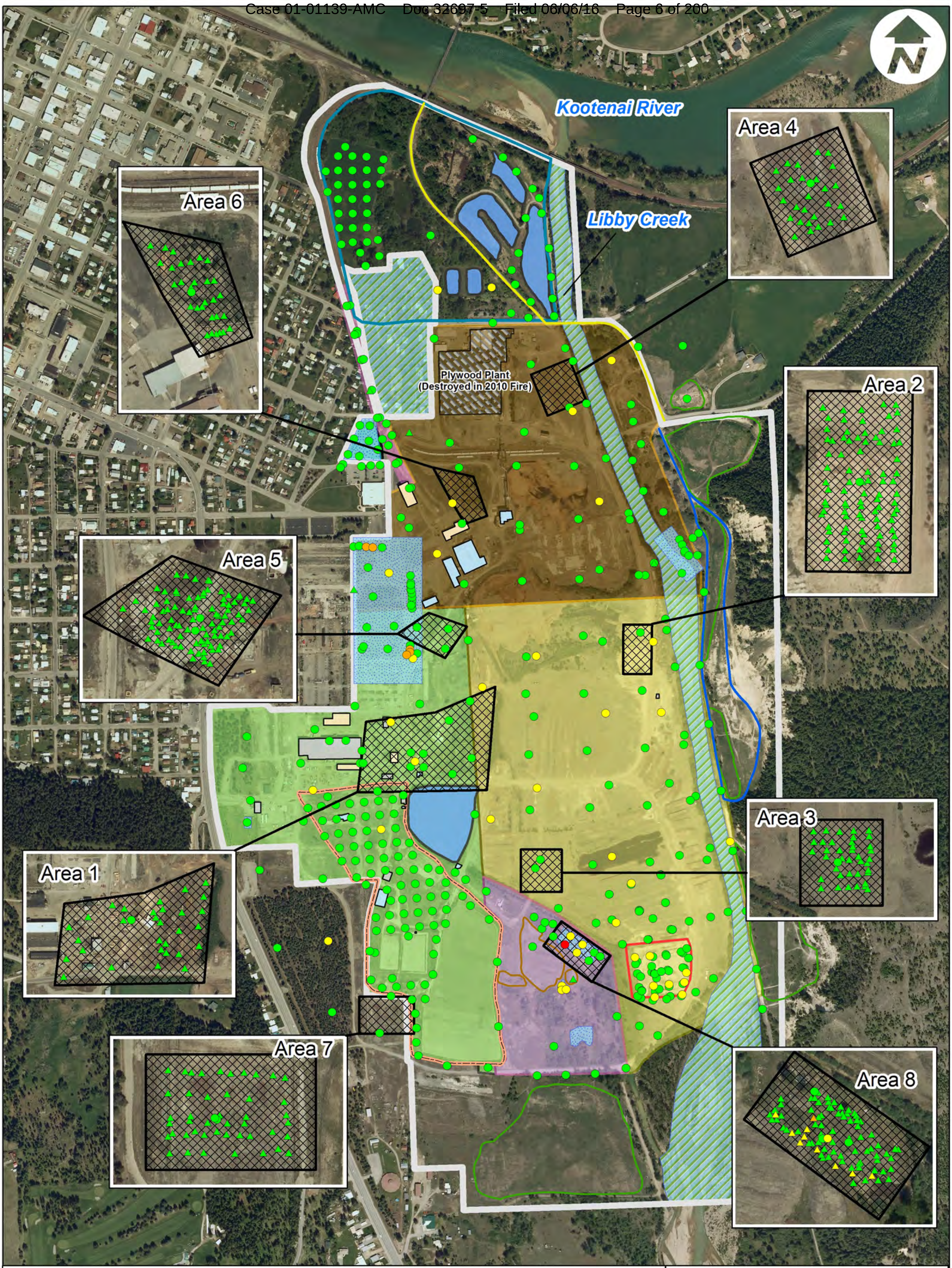
Figure 6-8

Nature and Extent
Forest Pulaski ABS
Locations

CDM Smith

Path: R:\85158-OU3\3120.001-RA\GIS\MXD\ABS_Samples\ABS_SampleGrid_20130819.mxd


N
Kootenai River
Libby Creek
Plywood Plant (Destroyed in 2010 Fire)
Astrodome
Power House and Power House Office
Finger Jointer Processing Plant
Storage and Locomotive Shed
Pipe Shop
Shed 12
Log Yard Scale House (Occupied)
Truck Barn
Fire Hall
Central Maintenance
Wagner Shed
Steel Storage
Electric Pump House
Main Office
Electric Motor Shed
Office/Labratory
Chemical Storage Building
Intermediate Injection Building
Diesel Pump House
Bioreactor Building
Tank Farm Building
LTU Leachate (Building #1) (Vacant)
LTU Leachate (Building #2) (Vacant)
Legend
Bike Path (Unpaved or Partially Paved)
Bike Path (Paved, as of Sept. '10)
Storm Water Containment and Waste Water Lagoon Area
Waste Bark Piles Debris
Approved Waste Bark Disposal Area
MotoX Track
Libby Groundwater Superfund Site
OU5 Boundary
OU4 (limits are approximately in vicinity of Libby Creek)
Surface Water
Buildings - Occupied
Buildings - Vacant
(Existing Buildings as of May 2013)
Buildings - Open Air (less than four walls)
Railroad Spur
Former Popping Plant
Lumber Yard
Former Champion Int. Tree Nursery
Log Storage Area
Southwest Area
Note: Some map objects adapted from CDM
HDR HDR Engineering, Inc.
OU5 Land Uses and Building Locations
Focused Feasibility Study
Operable Unit 5 - Libby Asbestos Site
Libby, Montana
DATE: MAY, 2013
Figure 6-9
0 0.075 0.15 0.225 0.3
Miles



LA Results

Grab Samples
- < 1%
- Trace
- Non-Detect

Composite Samples
- >= 1%
- < 1%
- Trace
- Non-Detect

- Bike Path (Unpaved or Partially Paved)
- Bike Path (Paved, as of Sept. '10)
- Storm Water Containment and Waste Water Lagoon Area
- Waste Bark Piles Debris
- Approved Waste Bark Disposal Area
- MotoX Track
- Libby Groundwater Superfund Site
- Worker ABS Areas
- OU5 Boundary
- OU4 (limits are approximately in vicinity of Libby Creek)
- Abatement Reponse Action Areas[1]

- Buildings - Occupied
- Buildings - Vacant (Existing Buildings as of May 2013)
- Buildings - Open Air (less than four walls)
- Surface Water
- Railroad Spur
- Former Popping Plant
- Lumber Yard
- Former Champion Int. Tree Nursery
- Log Storage Area
- Southwest Area

[1]*Results shown on Figure reflect testing done before abatement actions. See Figure 1-4 & Table 1-1 for details on response actions taken at OU5.*

HDR Engineering, Inc.

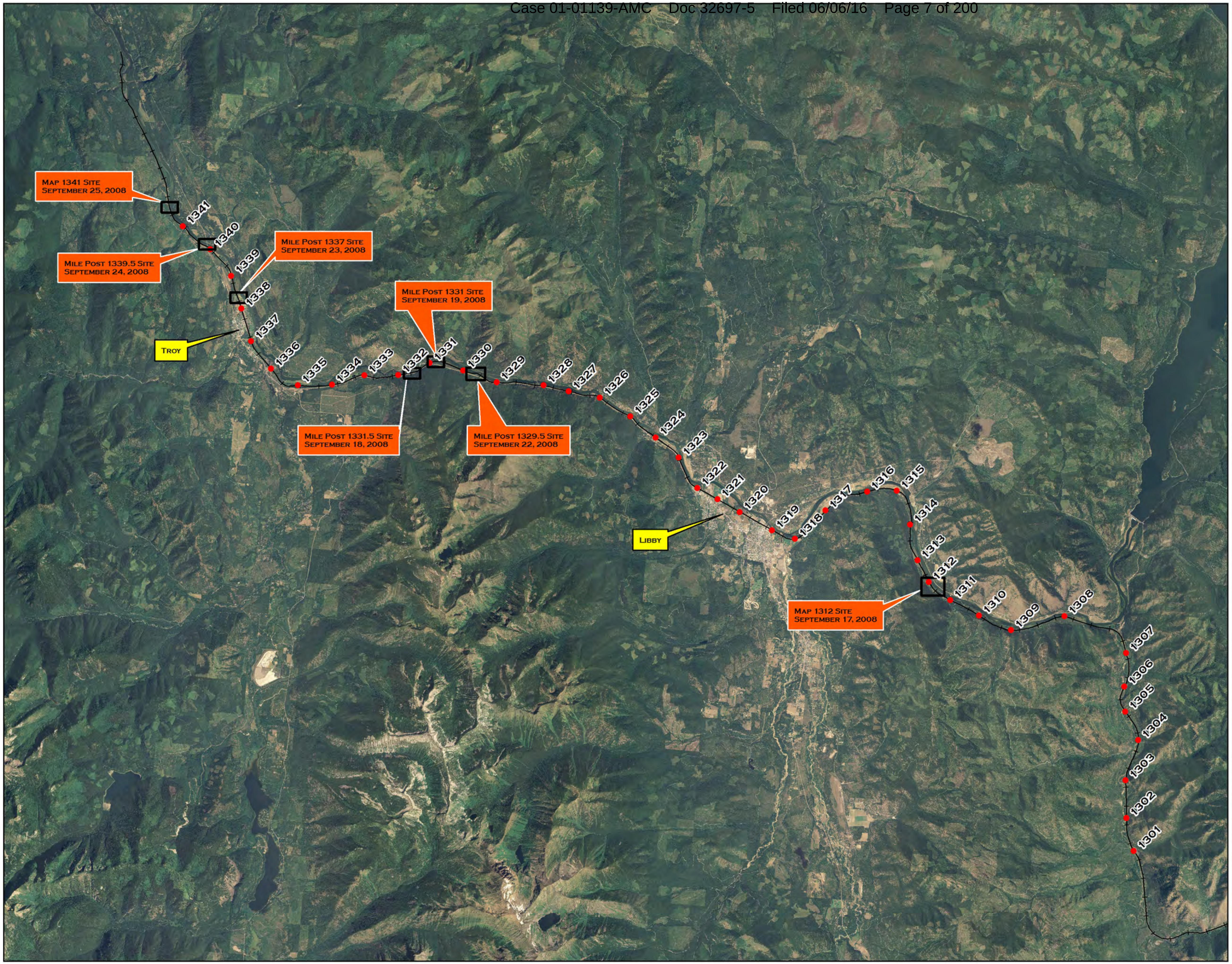
OU5 Outdoor ABS Areas

Remedial Investigation
Operable Unit 5 - Libby Asbestos Site
Libby, Montana

DATE: MAY, 2013

Figure 6-10

0 0.08 0.16 0.24 0.32 Miles



N
W E
S

Figure 6-11
OU6 Outdoor ABS Locations

Activity Based Sampling Summary Report
--
Worker Receptors

BNSF Kootenai River Sub
Libby, Montana

Legend

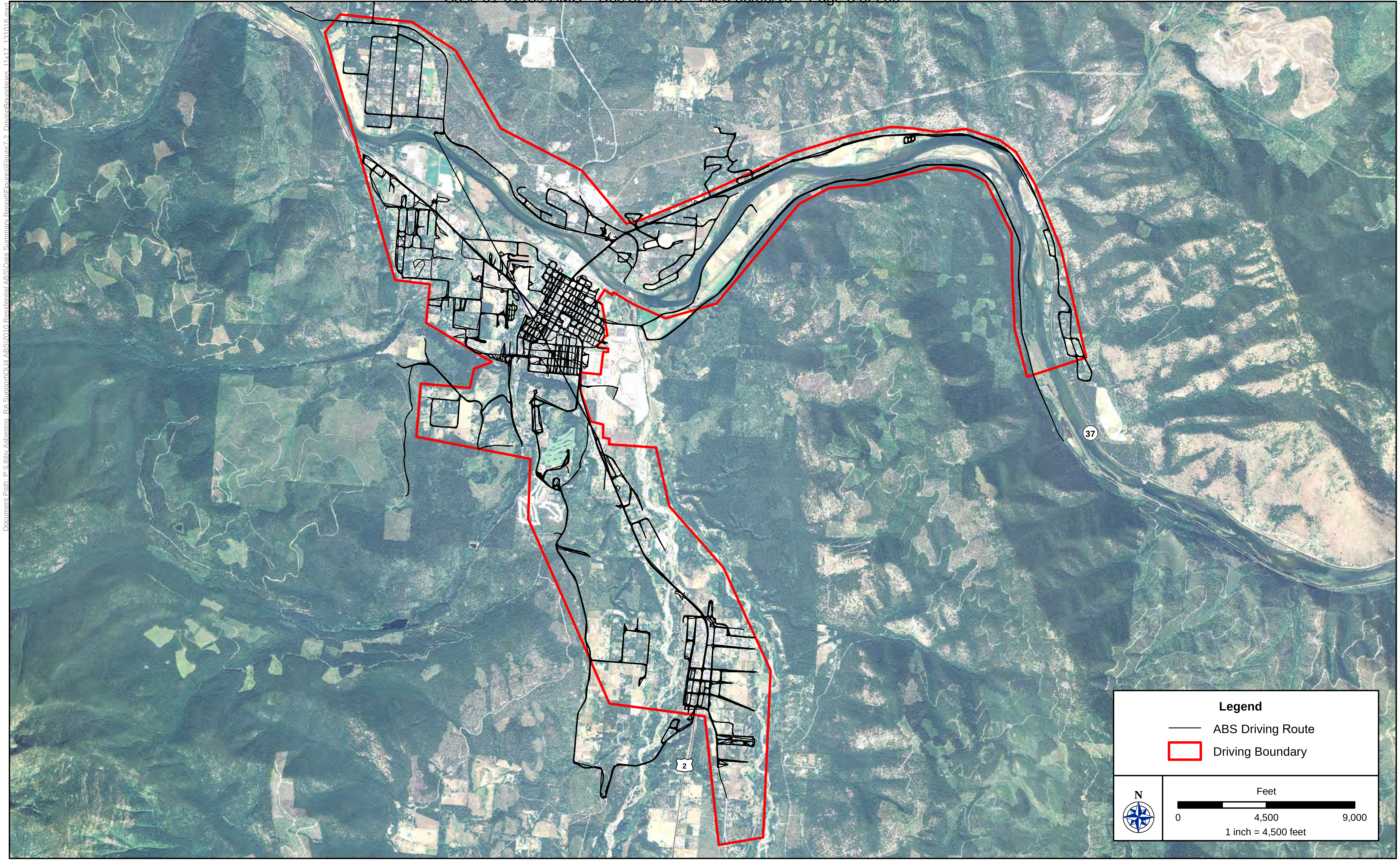
- Approximate Milepost Locations
- BNSF Railway

0 7,000 14,000 28,000
Scale In Feet

0 2 4
Scale In Miles

Project Number: 5539-140
Date: March 8, 2010
Drafted By: KLA
Reviewed By: SJC
Reference: 2006 Lincoln Aerial

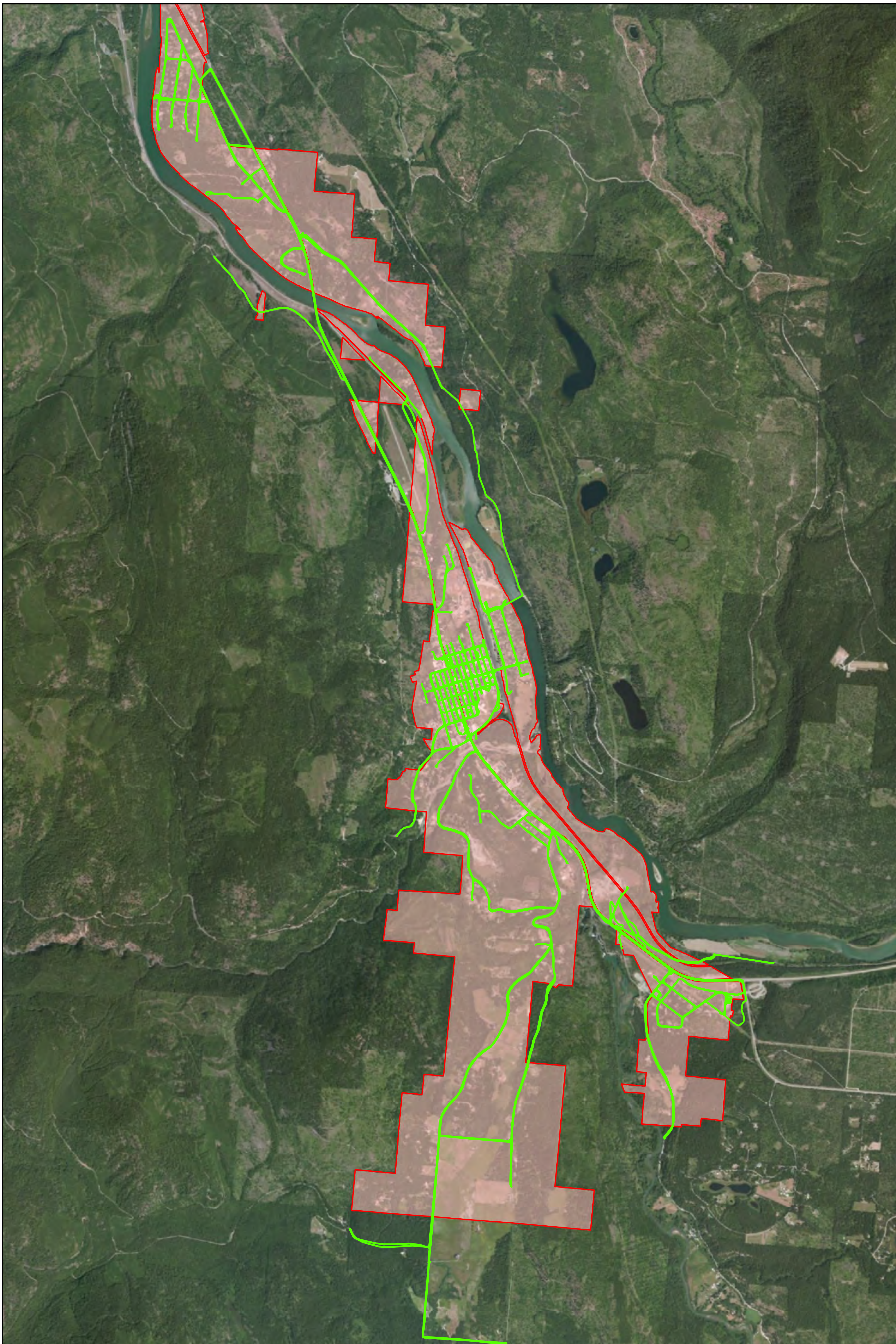
EMR Incorporated
Infrastructure and Environment
11 E. Superior St. Suite #260
Duluth, MN 55802
Phone: 218.625.2332
Fax:218.625.2337



CDM Smith

Libby
Driving Boundaries

FIGURE 6-12



LEGEND

ABS DRIVING ROUTE - 2011

OPERABLE UNIT 7 AREA

N

0 1 Miles

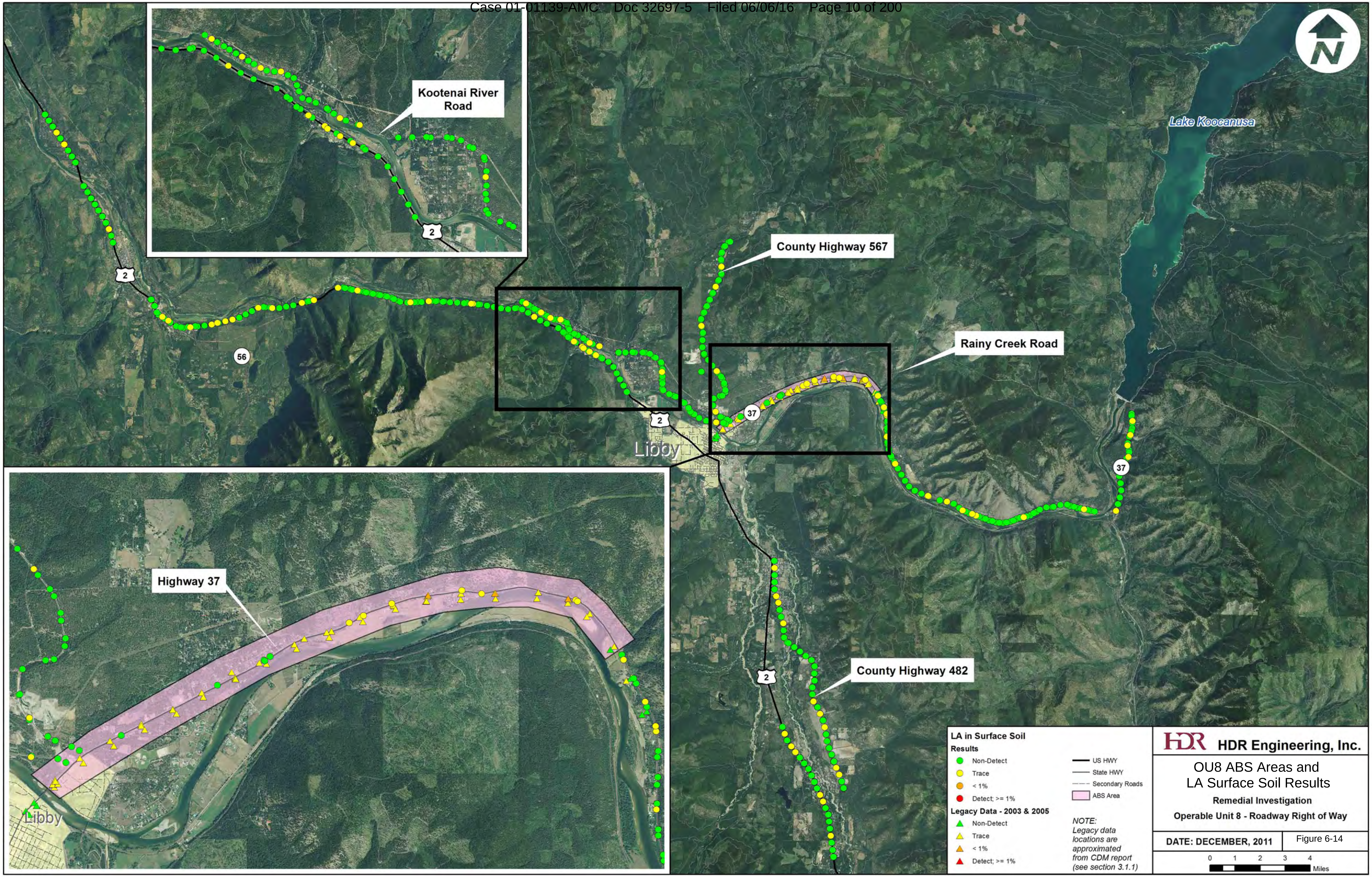
LIBBY ASBESTOS SUPERFUND SITE
LIBBY, MONTANA

FIGURE 6-12

TROY DRIVING BOUNDARIES

TETRA TECH EM INC.

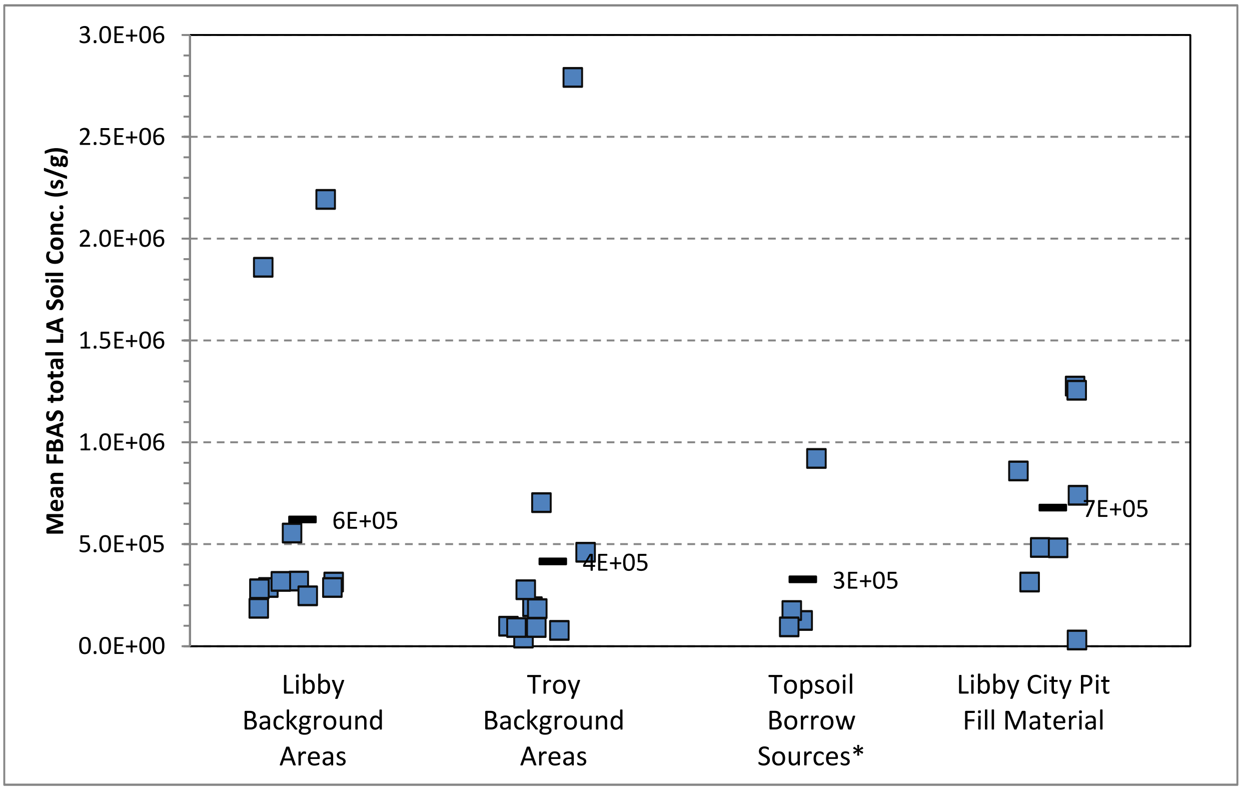
Driving_Track_Base_Map_021414.mxd - DWH - TTEMI HELENA



Kootenai River Road
County Highway 567
Rainy Creek Road
Lake Koocanusa
Libby
Highway 37
County Highway 482
2
56
37
LA in Surface Soil
Results
Non-Detect
Trace
< 1%
Detect; >= 1%
Legacy Data - 2003 & 2005
Non-Detect
Trace
< 1%
Detect; >= 1%
US HWY
State HWY
Secondary Roads
ABS Area
NOTE:
Legacy data locations are approximated from CDM report (see section 3.1.1)
HDR Engineering, Inc.
OU8 ABS Areas and LA Surface Soil Results
Remedial Investigation
Operable Unit 8 - Roadway Right of Way
DATE: DECEMBER, 2011
Figure 6-14
0 1 2 3 4
Miles

FIGURE 6-15

Scatterplot of Total LA Soil Concentrations in Background Soils



*Only includes sources within the Kootenai Valley.

Each square represents the measured concentration for each location.

The mean concentration for each soil type is shown as a horizontal bar.

Notes:

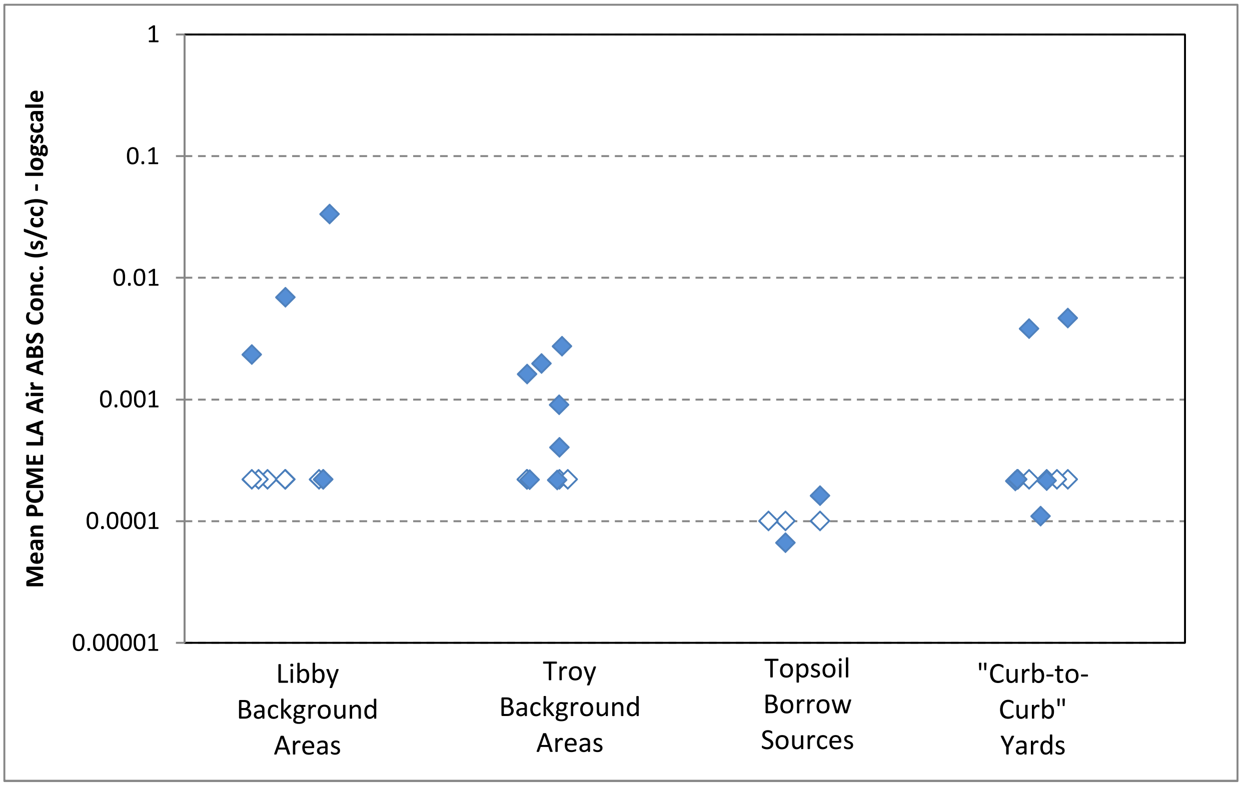
FBAS = fluidized bed asbestos segregator

LA = Libby amphibole

s/g = structures per gram

FIGURE 6-16. Example Photographs of the "Bucket of Dirt" ABS Activities

FIGURE 6-17. SCATTERPLOT OF PCME LA AIR CONCENTRATIONS IN BORROW SOURCES, BACKGROUND AREAS, AND CURB-TO-CURB PROPERTIES



Non-detects are shown as open symbols and plotted at the target sensitivity.

Notes:

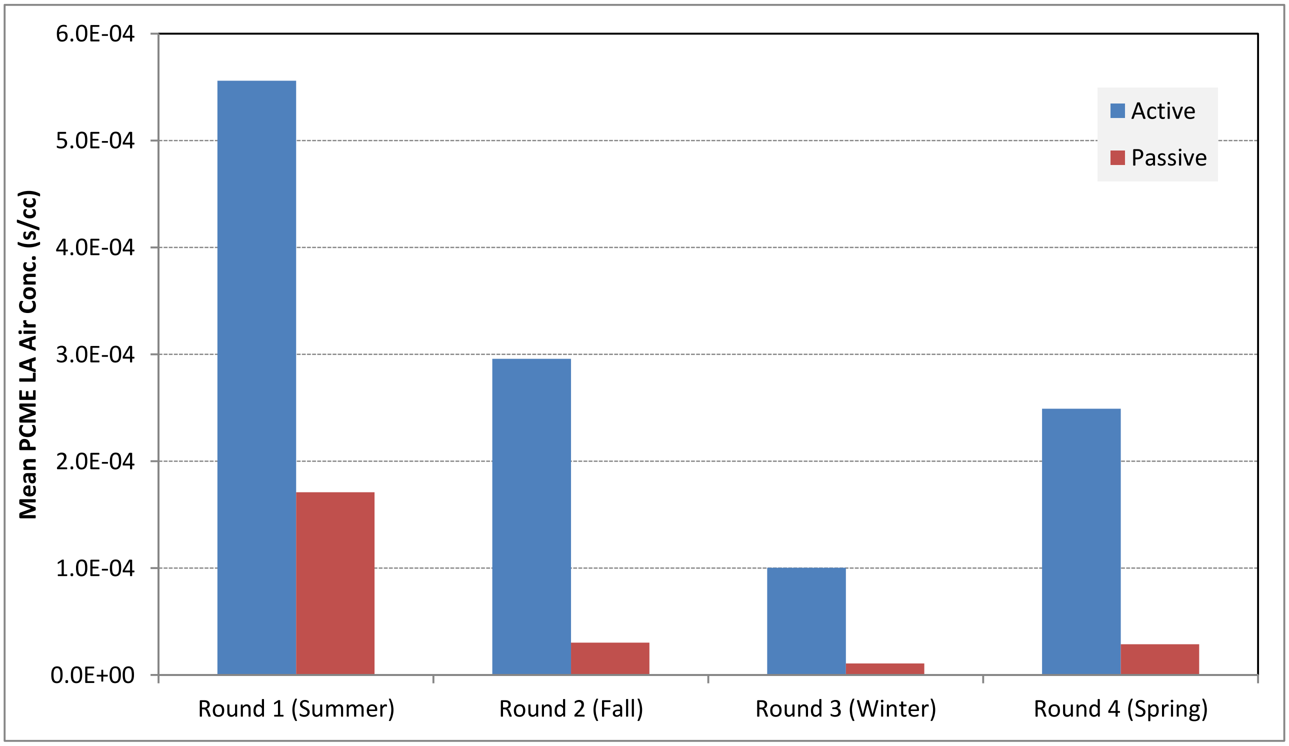
ABS = activity-based sampling

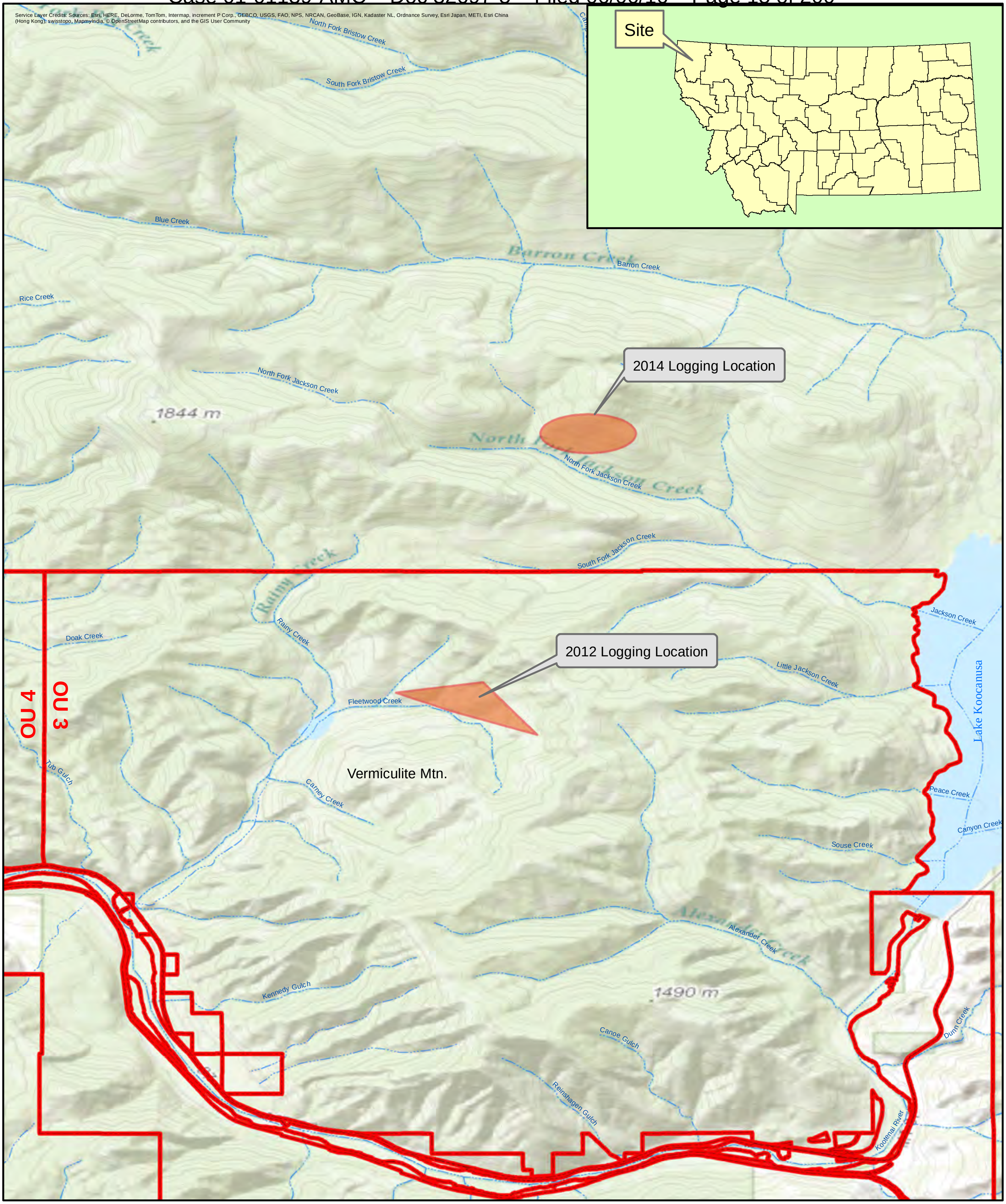
LA = Libby amphibole

s/cc = structures per cubic centimeter

Conc. = concentration

FIGURE 7-1
ILLUSTRATION OF SEASONAL VARIABILITY IN INDOOR ABS AIR CONCENTRATIONS
Libby Asbestos Superfund Site





Legend

- Commercial Logging Study Area
- Operable Unit 3
- Streams

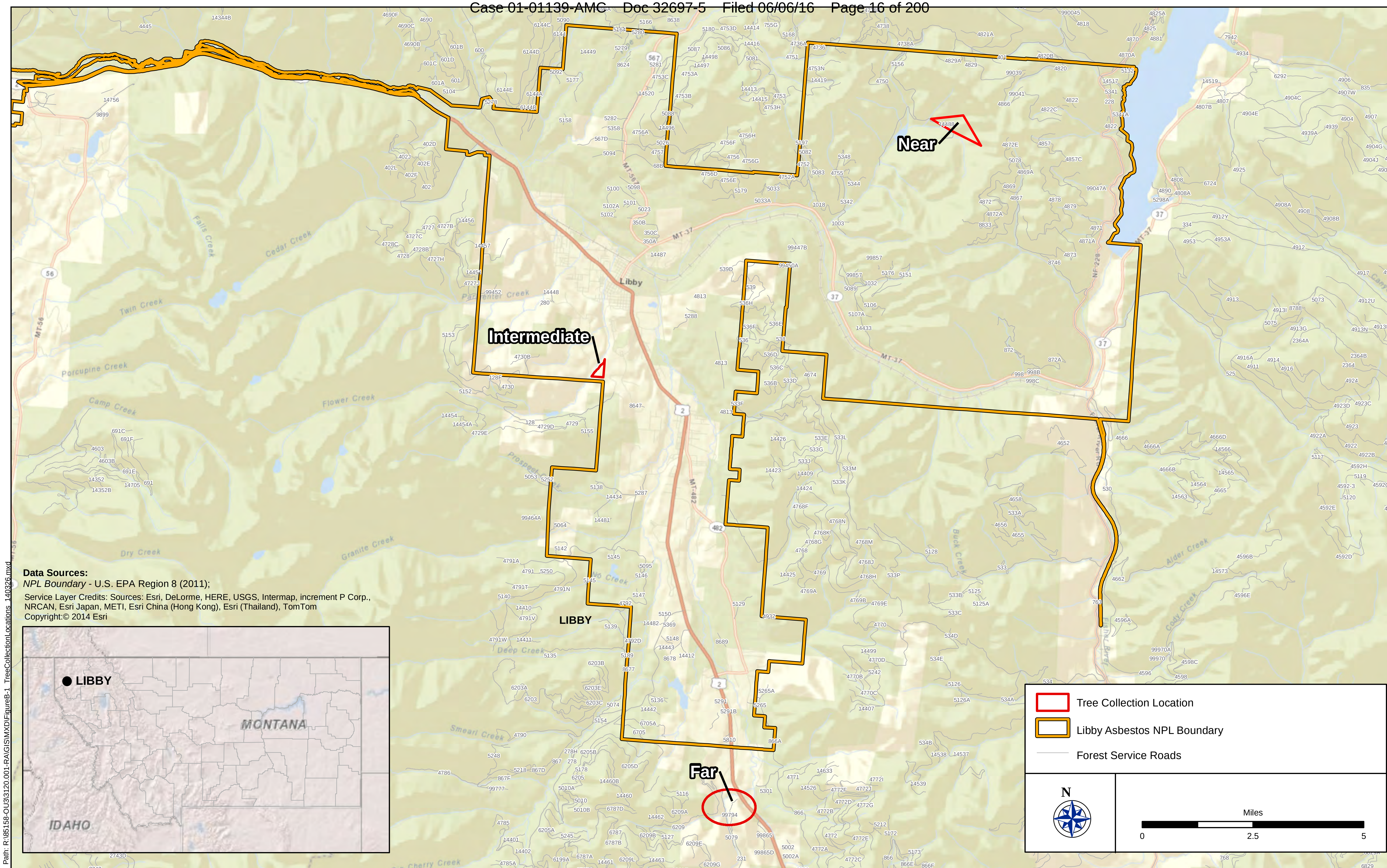
1.5 0.75 0 1.5 Miles

N

1:100,000
1 inch = 8,333 feet

Figure 8-1
Commercial Logging ABS Areas

CDM Smith



Data Sources:
NPL Boundary - U.S. EPA Region 8 (2011);
Service Layer Credits: Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom
Copyright:© 2014 Esri

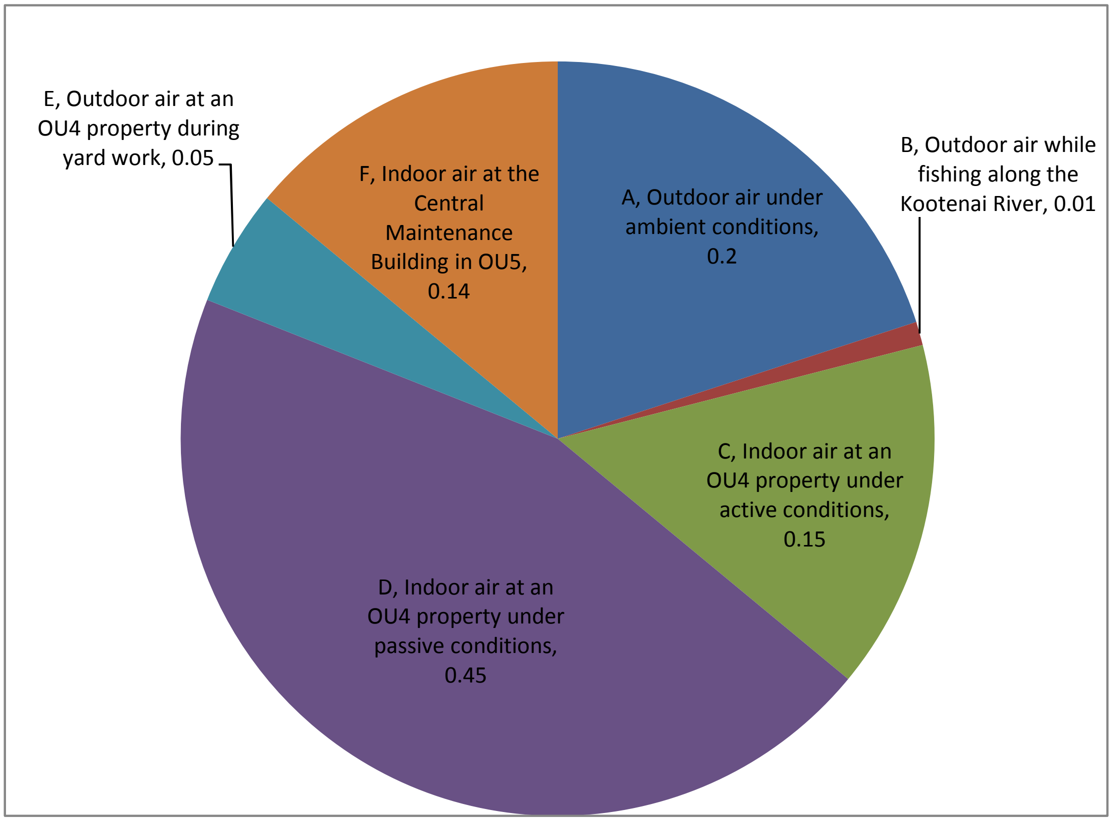
Path: R:\85158-OU3\3120.001-RA\GIS\MXD\FigureB-1_TreeCollectionLocations_140326.mxd

CDM Smith

Tree Collection Locations

FIGURE 8-2

FIGURE 9-1. ILLUSTRATION OF CUMULATIVE ASSESSMENT TWF APPROACH

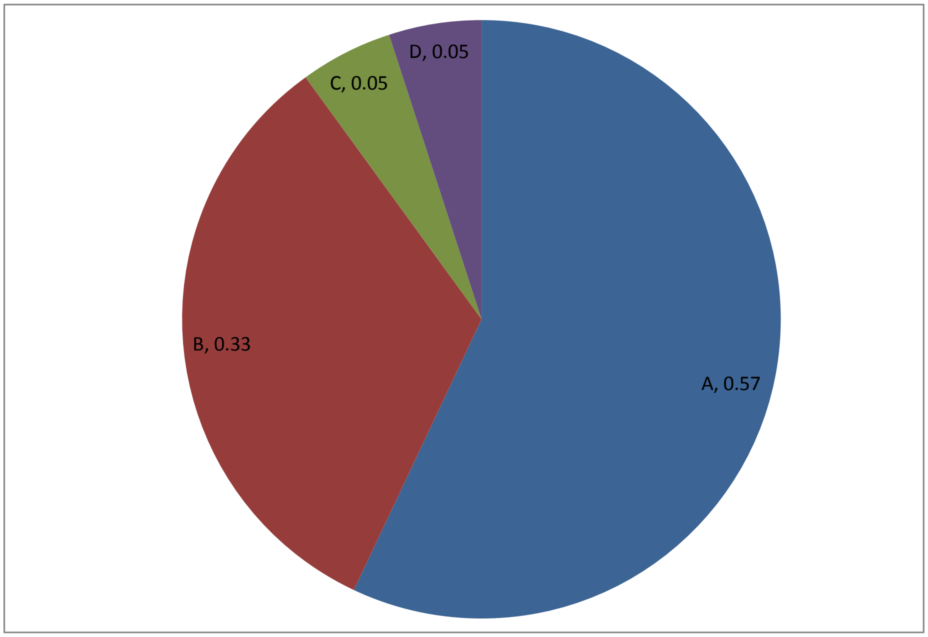


Exposure Scenario		TWF	% of total
A	Outdoor air under ambient conditions	0.2	20%
B	Outdoor air while fishing along the Kootenai River	0.01	1%
C	Indoor air at an OU4 property under active conditions	0.15	15%
D	Indoor air at an OU4 property under passive conditions	0.45	45%
E	Outdoor air at an OU4 property during yard work	0.05	5%
F	Indoor air at the Central Maintenance Building in OU5	0.14	14%
	cumulative:	**1.00**	

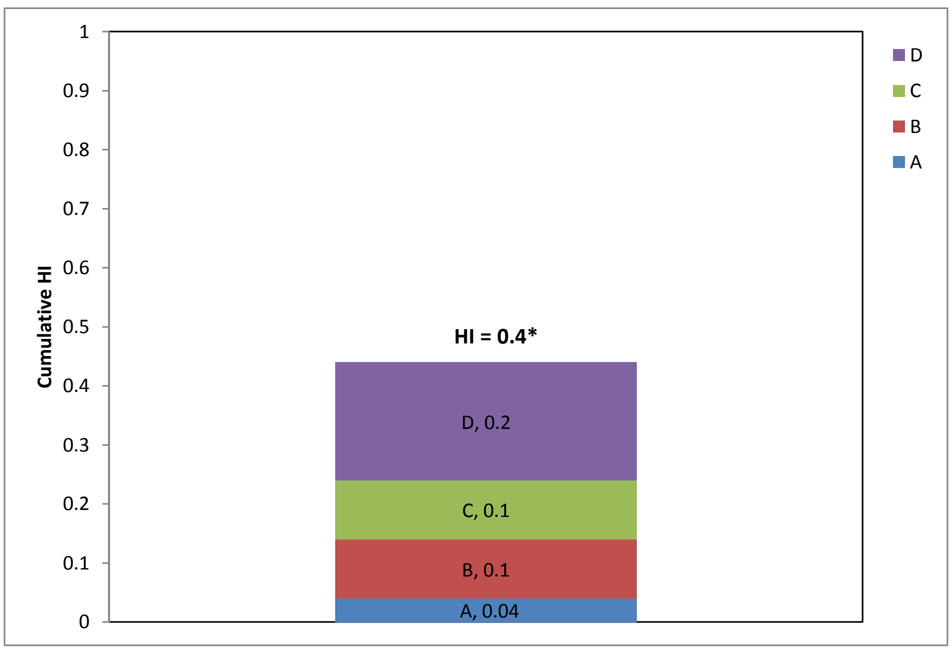
FIGURE 9-2a. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 1

["baseline" residential]

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI

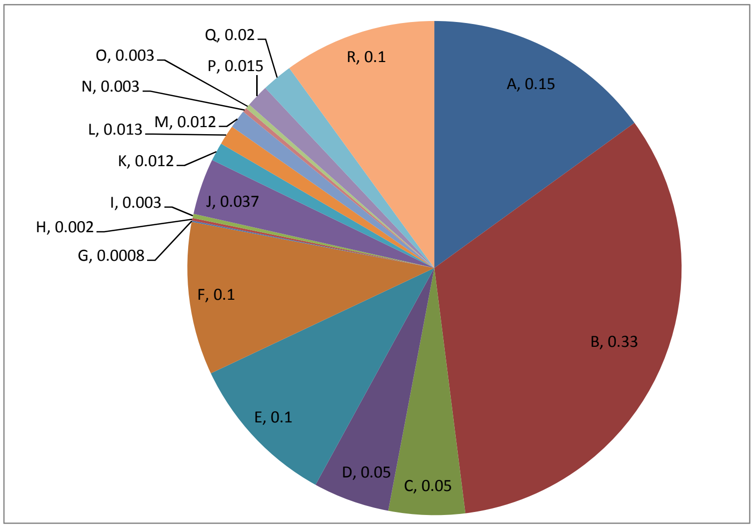


	Exposure Scenario	TWF		Risk Estimates		
		Value	**% of total**	**Risk**	**HQ**	**% of total**
A	Ambient air, OU4	0.57	57%	6E-07	0.04	10%
B	Indoor air, OU4, post-removal, resident, passive	0.33	33%	2E-06	0.1	25%
C	Indoor air, OU4, post-removal, resident,active	0.05	5%	2E-06	0.1	25%
D	Outdoor air, yard soil, curb-to-curb	0.05	5%	3E-06	0.2	50%
	cumulative*:	**1.000**		**7E-06**	**0.4**	

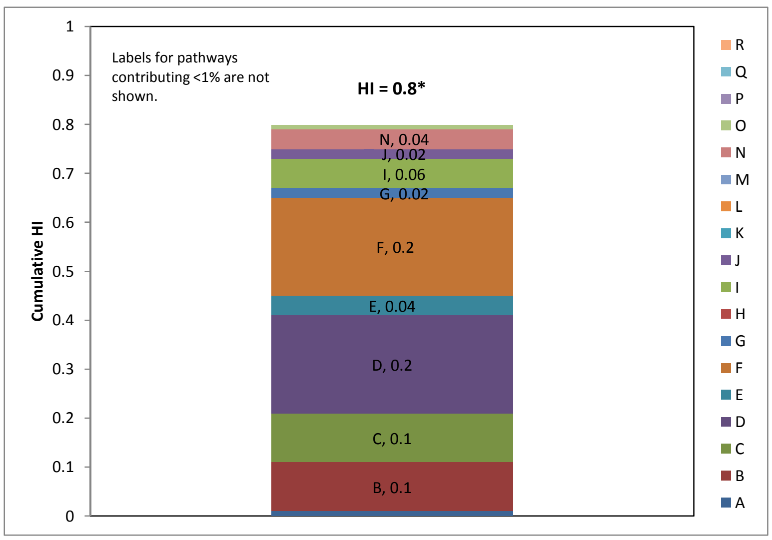
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

FIGURE 9-2b. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 1

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI

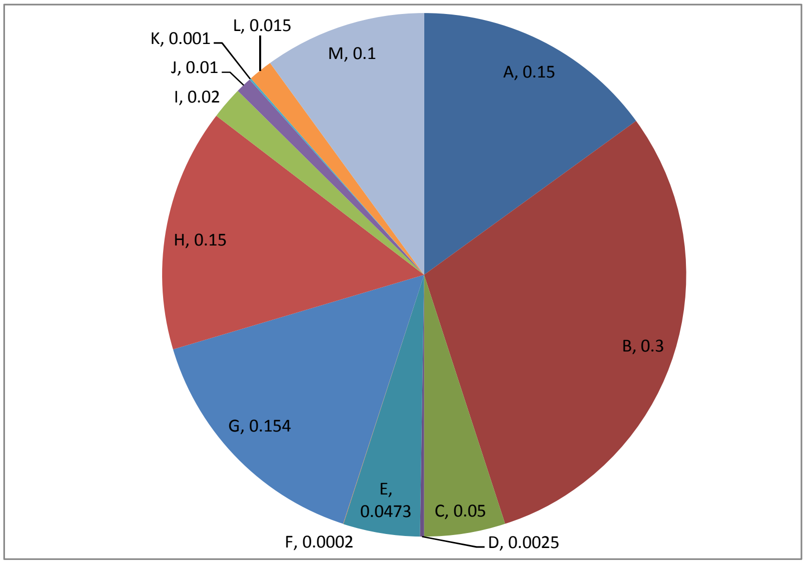


	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.15	15%	2E-07	0.01	1%
B	Indoor air, OU4, post-removal, resident, passive	0.33	33%	2E-06	0.1	13%
C	Indoor air, OU4, post-removal, resident,active	0.05	5%	2E-06	0.1	13%
D	Outdoor air, yard soil, curb-to-curb	0.05	5%	3E-06	0.2	25%
E	Indoor air, OU4, no removal, worker, passive	0.1	10%	7E-07	0.04	5%
F	Indoor air, OU4, no removal, worker, active	0.1	10%	4E-06	0.2	25%
G	Outdoor air, OU4, Libby Middle, student	0.00082	0.08%	3E-07	0.02	3%
H	Outdoor air, OU4, Koot. Valley HS, student	0.0016	0.2%	0E+00	0	0%
I	Outdoor air, OU4, Libby Elem., student	0.0029	0.3%	9E-07	0.06	8%
J	Indoor air, OU4, student, Elem. School	0.037	4%	4E-07	0.02	3%
K	Outdoor air, OU7, Golf course, adult	0.012	1%	0E+00	0	0%
L	Outdoor air, OU4, biking, adult	0.013	1%	0E+00	0	0%
M	Outdoor air, OU5, MotoX, participant	0.012	1%	0E+00	0	0%
N	Outdoor air, OU4, LUA soil, ATV, A	0.0030	0.3%	6E-07	0.04	5%
O	Outdoor air, OU3, forest, hiking, far	0.0030	0.3%	1E-07	0.008	1%
P	Outdoor air, OU3, Kootenai, fishing	0.015	1%	0E+00	0	0%
Q	Outdoor air, OU8, Driving in Libby	0.020	2%	0E+00	0	0%
R	Offsite	0.1	10%	0E+00	0	0%
	cumulative*:	**1.000**		**1E-05**	**0.8**	

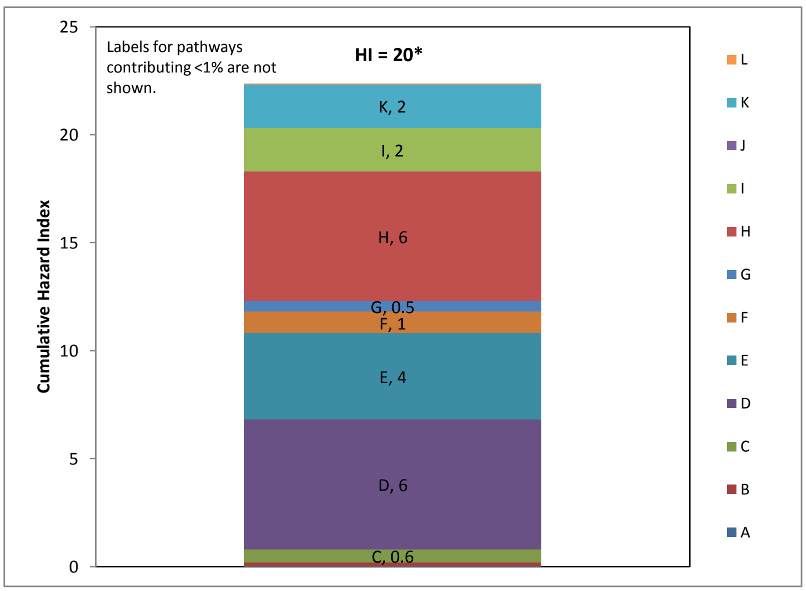
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

FIGURE 9-3. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 2

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI

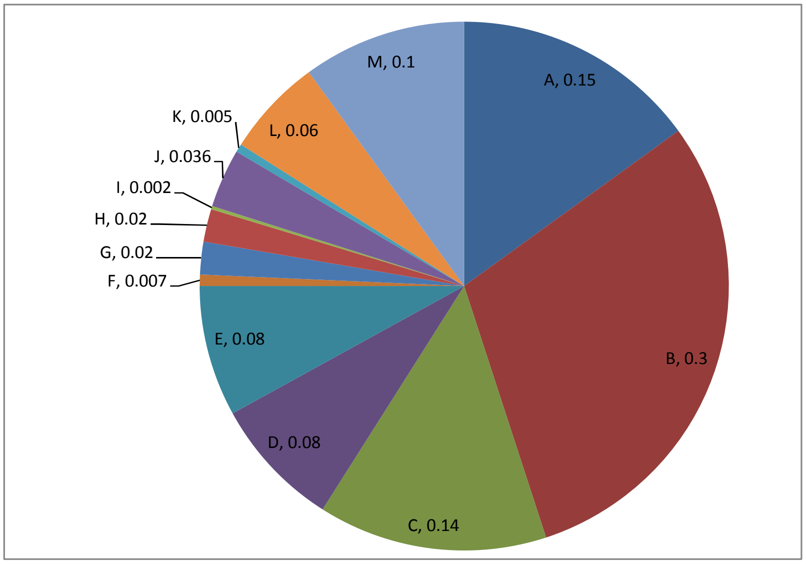


	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.15	15%	2E-07	0.01	0.1%
B	Indoor air, OU4, pre-removal, resident, passive	0.3	30%	3E-06	0.2	1%
C	Indoor air, OU4, pre-removal, resident, active	0.05	5%	8E-06	0.6	3%
C	Outdoor air, OU4, yard soil, B2/C, high	0.0025	0.3%	9E-05	6	30%
E	Outdoor air, OU4, yard soil, B2/C, typical	0.0473	5%	6E-05	4	20%
F	Outdoor air, OU4, subsurface soil, resident, B2/C	0.0002	0.02%	2E-05	1	5%
G	Indoor air, OU4, pre-removal, worker, passive	0.154	15%	7E-06	0.5	3%
H	Indoor air, OU4, pre-removal, worker, active	0.15	15%	8E-05	6	30%
I	Outdoor air, OU3, Rainy Creek, hiking	0.02	2%	3E-05	2	10%
J	Outdoor air, OU3, forest, wood harvesting, near	0.01	1%	2E-07	0.02	0.1%
K	Indoor air, Woodstove ash, near	0.001	0.1%	2E-05	2	10%
L	Outdoor air, OU8, ATV	0.015	2%	5E-07	0.03	0.2%
M	Offsite	0.1	10%	0E+00	0	0%
	cumulative*:	**1.00**		**3E-04**	**20**	

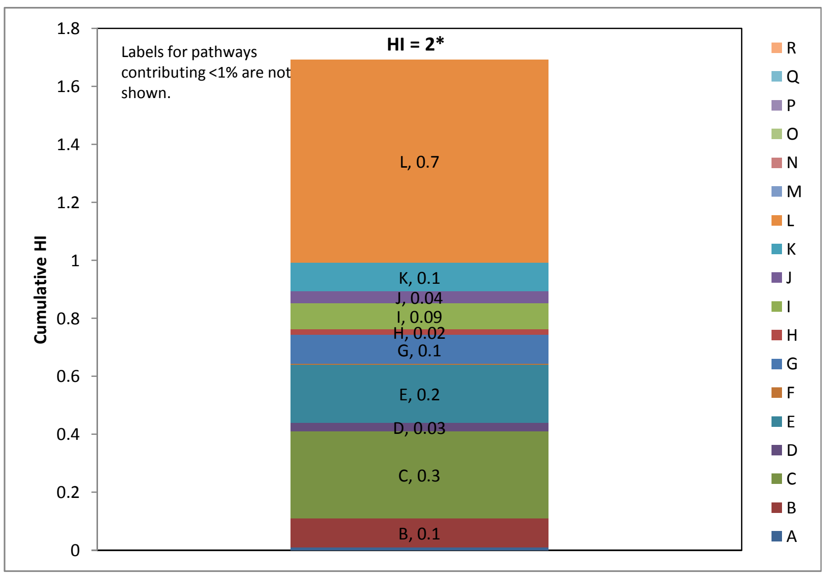
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

FIGURE 9-4. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 3

Panel A: Exposure Scenario Contribution to Cumulative TWF



Panel B: Exposure Scenario Contribution to Cumulative HI

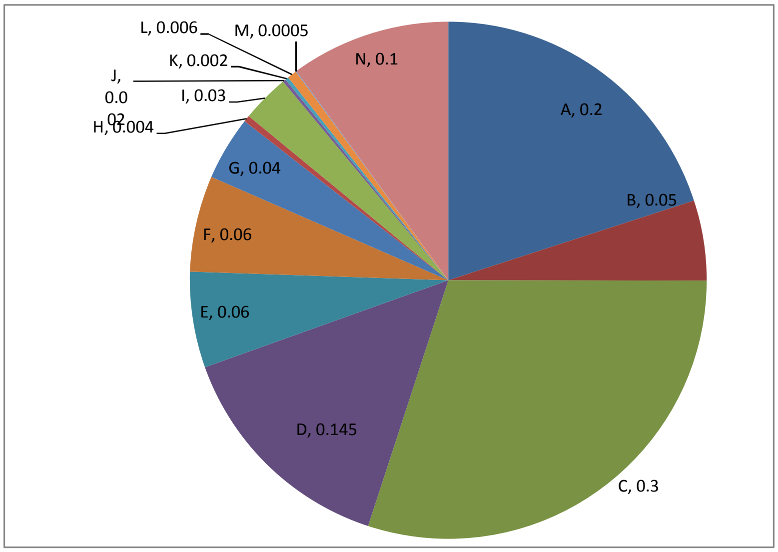


	Exposure Scenario	TWF		Risk Estimates		
		Value	**% of total**	**Risk**	**HQ**	**% of total**
A	Ambient air, OU4	0.15	15%	2E-07	0.01	1%
B	Indoor air, OU4, post-removal, resident, passive	0.3	30%	2E-06	0.1	5%
C	Indoor air, OU4, post-removal, resident,active	0.14	14%	4E-06	0.3	15%
D	Indoor air, OU4, no removal, worker, passive	0.08	8%	5E-07	0.03	2%
E	Indoor air, OU4, no removal, worker, active	0.08	8%	3E-06	0.2	10%
F	Outdoor air, OU5, biking, adult	0.007	0.7%	5E-08	0.003	0.2%
G	Outdoor air, OU3, forest, hiking, intermed.	0.02	2%	2E-06	0.1	5%
H	Outdoor air, OU7, Park, adult	0.02	2%	4E-07	0.02	1%
I	Outdoor air, OU4, yard soil, A, high	0.002	0.2%	1E-06	0.09	5%
J	Outdoor air, OU4, yard soil, A, typical	0.036	4%	7E-07	0.04	2%
K	Outdoor air, OU3, forest, campfire, intermed.	0.005	0.5%	2E-06	0.1	5%
L	Indoor air, OU5, Cent. Maint. Bldg, worker, active	0.06	6%	1E-05	0.7	35%
M	Offsite	0.1	10%	0E+00	0	0%
	cumulative*:	**1.000**		**3E-05**	**2**	

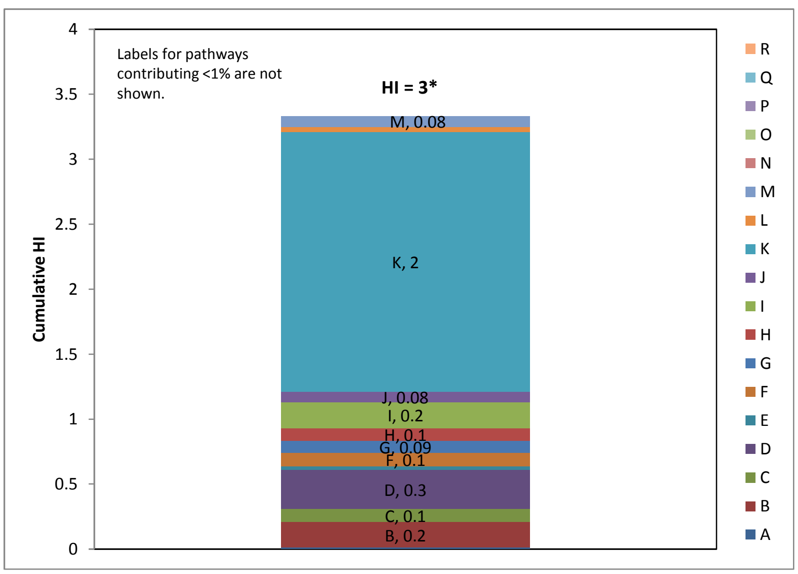
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

FIGURE 9-5. CUMULATIVE ASSESSMENT FOR RECEPTOR EXAMPLE 4

Panel A: Exposure Scenario Contribution to Cumulative TWF



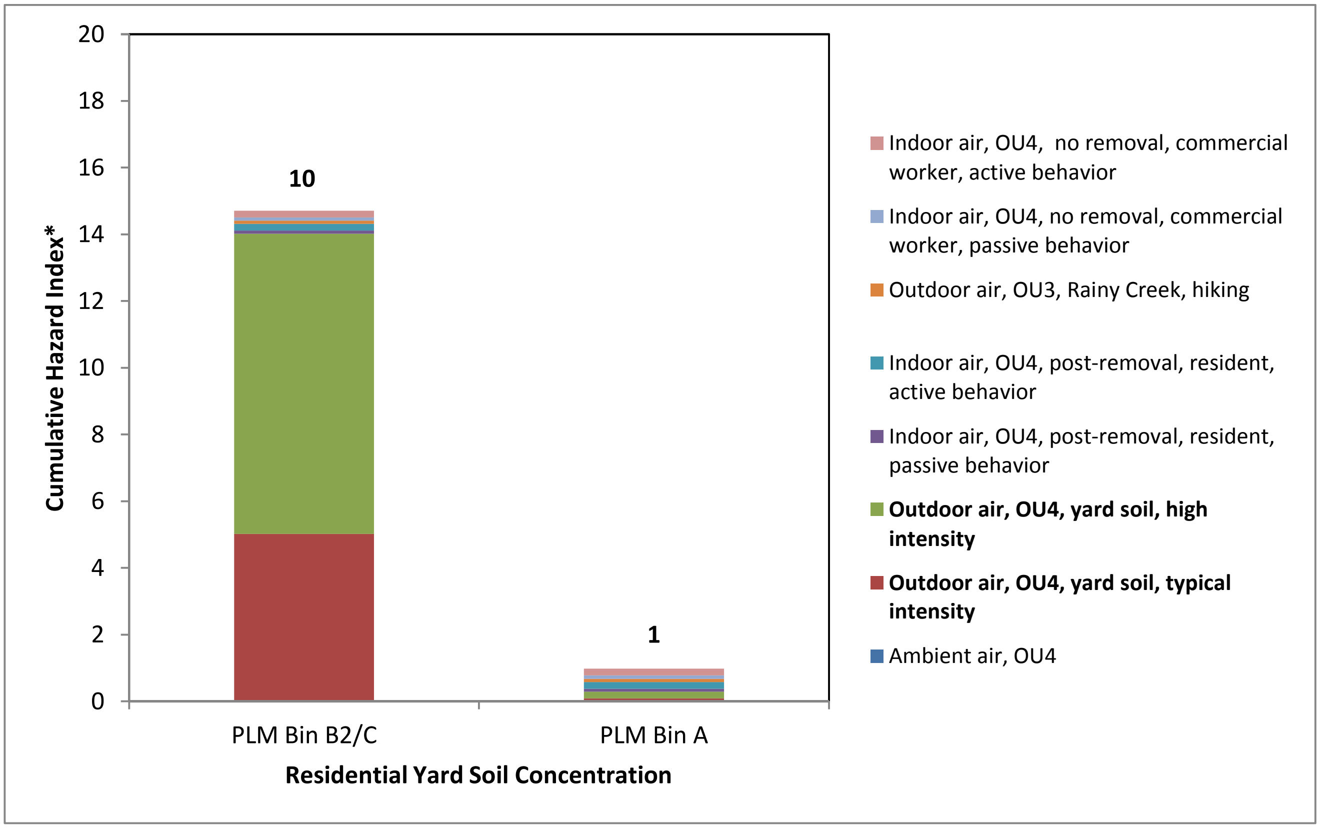
Panel B: Exposure Scenario Contribution to Cumulative HI



	Exposure Scenario	TWF		Risk Estimates		
		Value	% of total	Risk	HQ	% of total
A	Ambient air, OU4	0.2	20%	2E-07	0.01	0.3%
B	Outdoor air, yard soil, curb-to-curb	0.05	5%	3E-06	0.2	7%
C	Indoor air, OU4, post-removal, resident, passive	0.3	30%	2E-06	0.1	3%
D	Indoor air, OU4, post-removal, resident,active	0.145	15%	4E-06	0.3	10%
E	Indoor air, OU4, no removal, worker, passive	0.06	6%	4E-07	0.03	1%
F	Indoor air, OU4, no removal, worker, active	0.06	6%	2E-06	0.1	3%
G	Ambient air, OU3	0.04	4%	1E-06	0.09	3%
H	Outdoor air, OU3, forest, campfire, intermed.	0.004	0.4%	2E-06	0.1	3%
I	Outdoor air, OU3, forest, hiking, intermed.	0.03	3%	3E-06	0.2	7%
J	Outdoor air, OU3, forest, logging near, felling	0.002	0.2%	1E-06	0.08	3%
K	Outdoor air, OU3, forest, logging near, skidding	0.002	0.2%	3E-05	2	67%
L	Outdoor air, OU3, forest, USFS worker, intermed.	0.006	0.6%	7E-07	0.04	1%
M	Outdoor air, OU3, forest, Pulaski, intermed.	0.0005	0.05%	1E-06	0.08	3%
N	Offsite	0.1	10%	0E+00	0	0%
	cumulative*:	**1.000**		**5E-05**	**3**	

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown in the table.

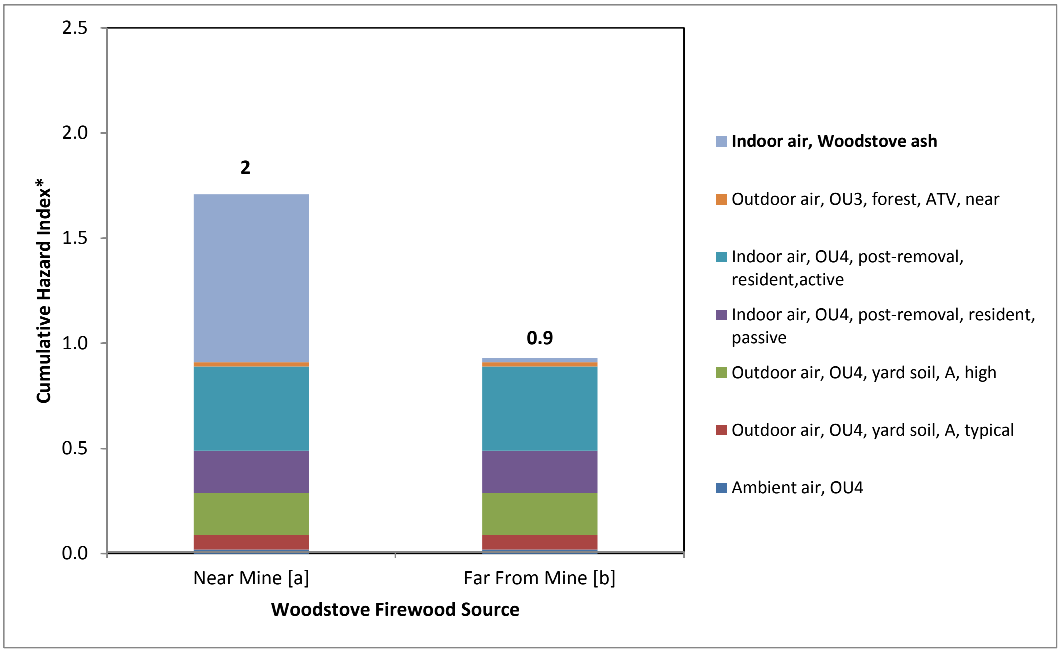
FIGURE 9-6
ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT YARD SOIL CONCENTRATIONS
Libby Asbestos Superfund Site



* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

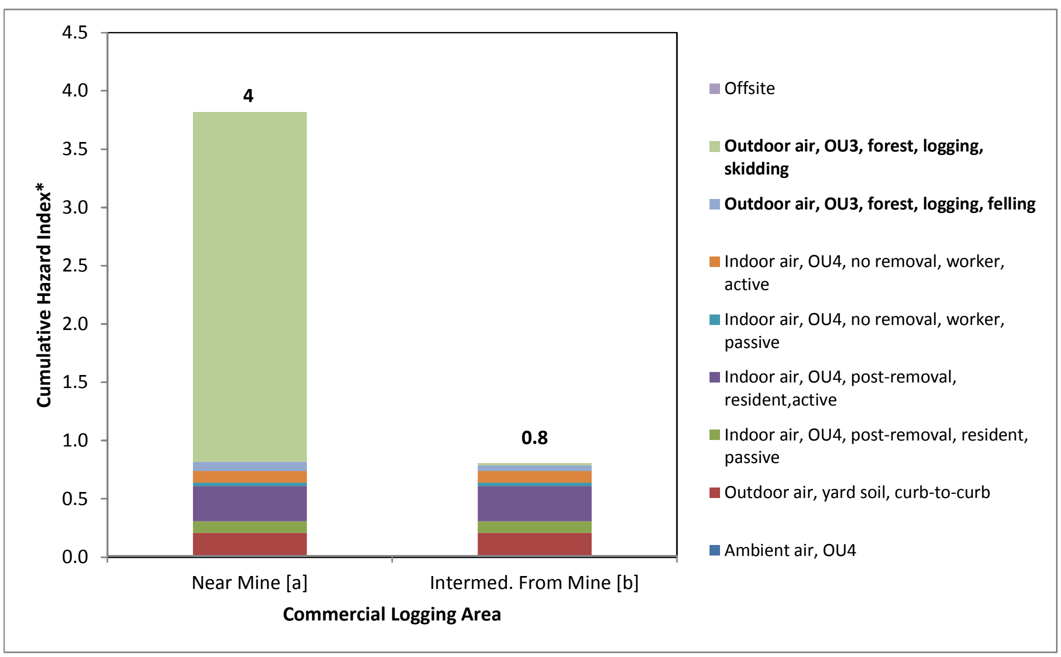
FIGURE 9-7
ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT ACTIVITY LOCATIONS
Libby Asbestos Superfund Site

Panel A: Woodstove Firewood Source



[a] Near mine: firewood collected approximately one mile downwind of the mine site
[b] Far from mine: firewood collected approximately 10 miles south of Libby and outside the current NPL boundary

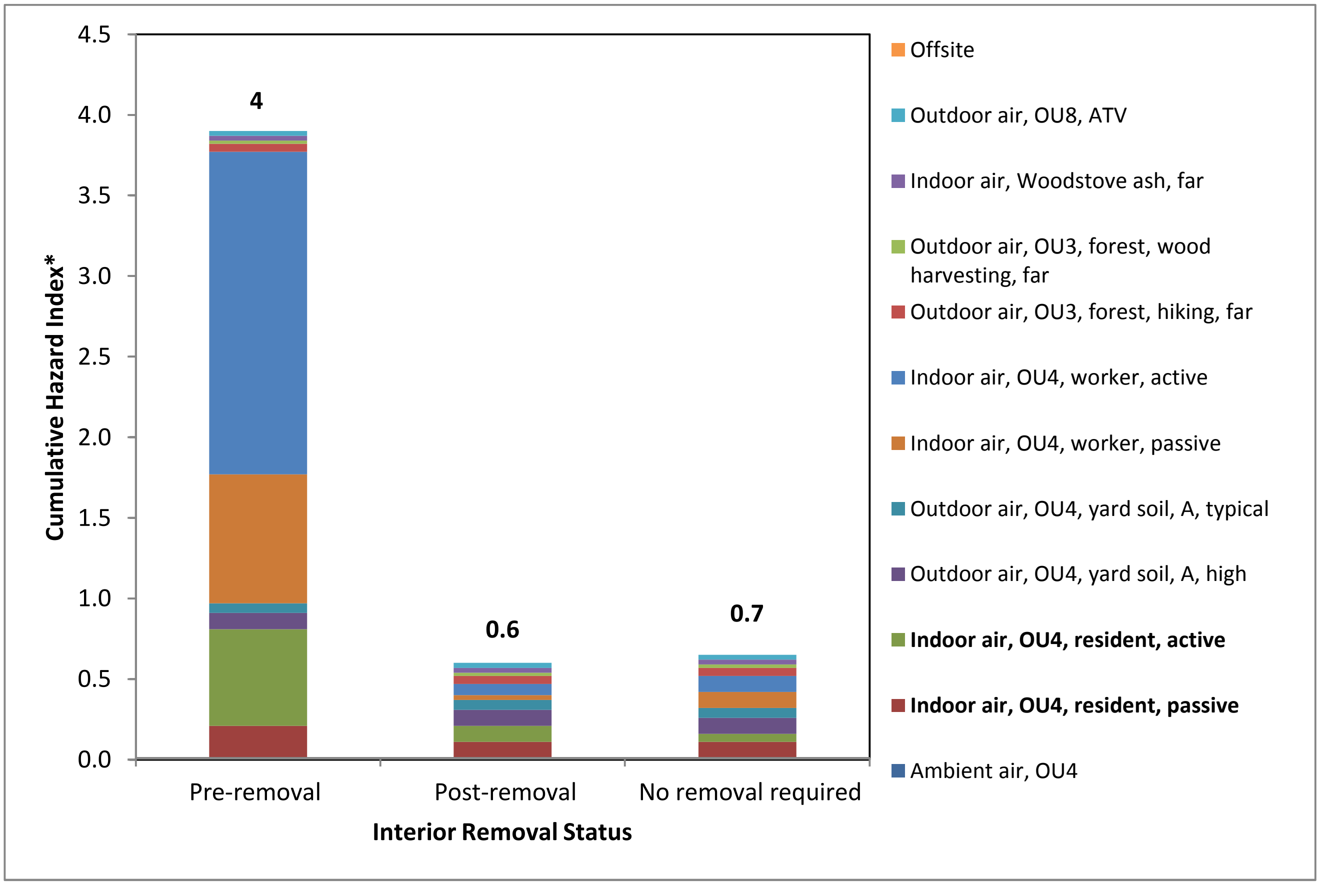
Panel B: Commercial Logging Area



[a] Near mine: Logging activities performed within 1 mile of the mine
[b] Intermed. from mine: Logging activities performed about 4 miles from the mine

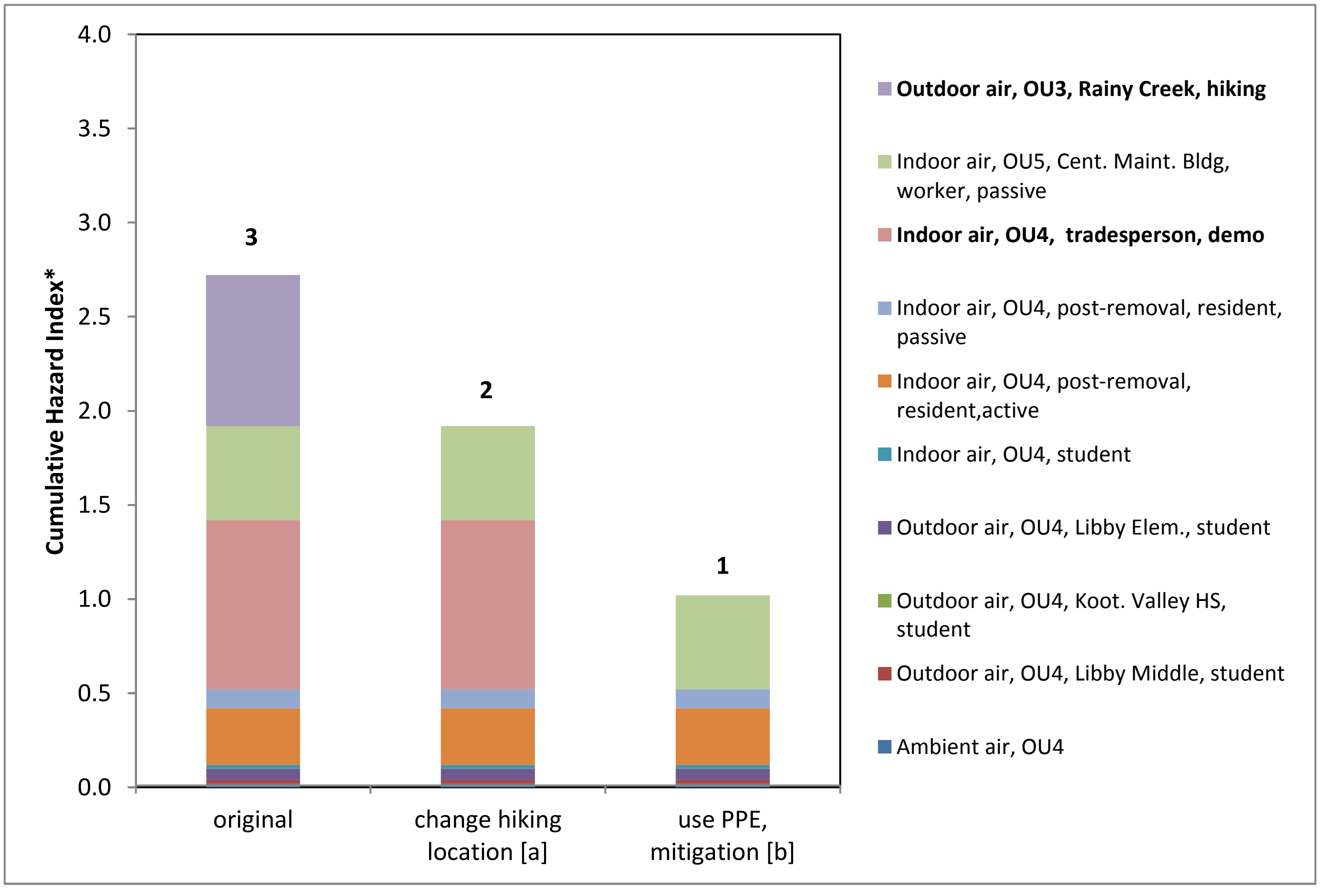
* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

FIGURE 9-8
ILLUSTRATION OF CUMULATIVE HI FOR DIFFERENT INTERIOR REMOVAL STATUS CONDITIONS
Libby Asbestos Superfund Site



* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

FIGURE 9-9
ILLUSTRATION OF CUMULATIVE HI CHANGE WHEN ADDRESSING MAIN RISK DRIVERS
Libby Asbestos Superfund Site



[a] Change hiking location from along Rainy Creek to along the Kootenai River

[b] Use appropriate personal protective equipment and employ dust mitigation measures during tradesperson demolition activities

* All HQ and HI values are expressed to one significant figure; thus, the height of the bar may appear different from the HI value shown.

Figure 10-1. Relationship Between Number of Structures Observed and Relative Uncertainty

Libby Asbestos Superfund Site

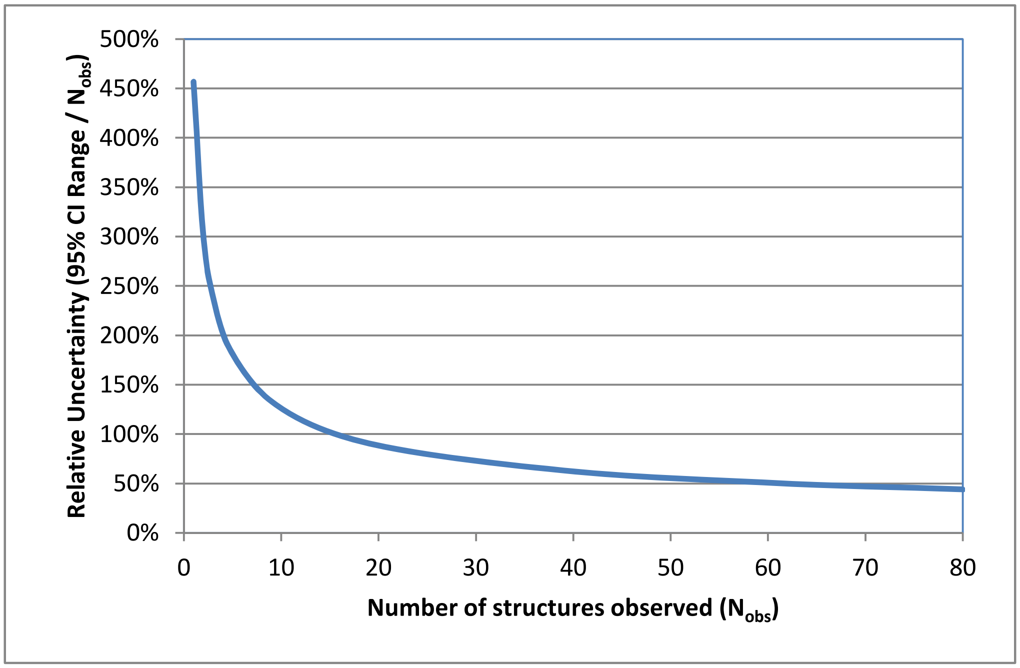
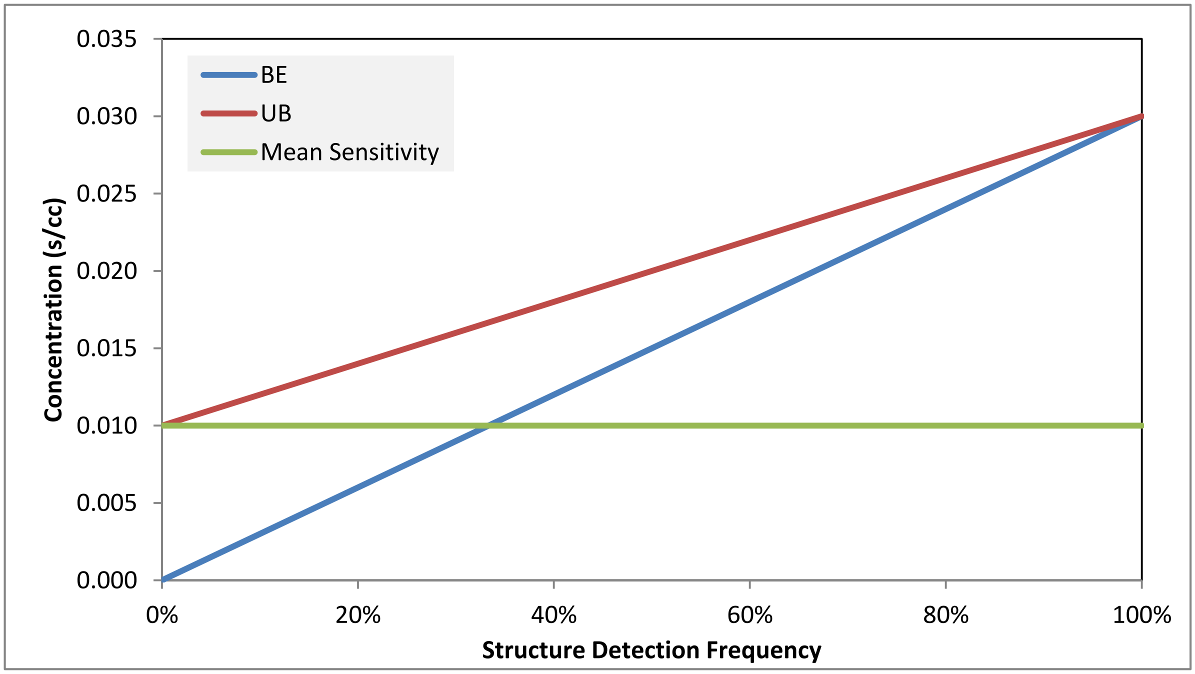


FIGURE 10-2
ILLUSTRATION OF BEST ESTIMATE AND UPPER-BOUND CONCENTRATIONS AS A FUNCTION OF STRUCTURE DETECTION FREQUENCY
Libby Asbestos Superfund Site



BE = Best estimate of the mean (calculated using zero for non-detects)

UB = Upper-bound estimate of the mean (calculated using the achieved sensitivity for non-detects)

% = percent

s/cc = structures per cubic centimeter

FIGURE 11-1. SUMMARY OF HQs FOR ALL AMBIENT AIR EXPOSURE SCENARIOS

Libby Asbestos Superfund Site

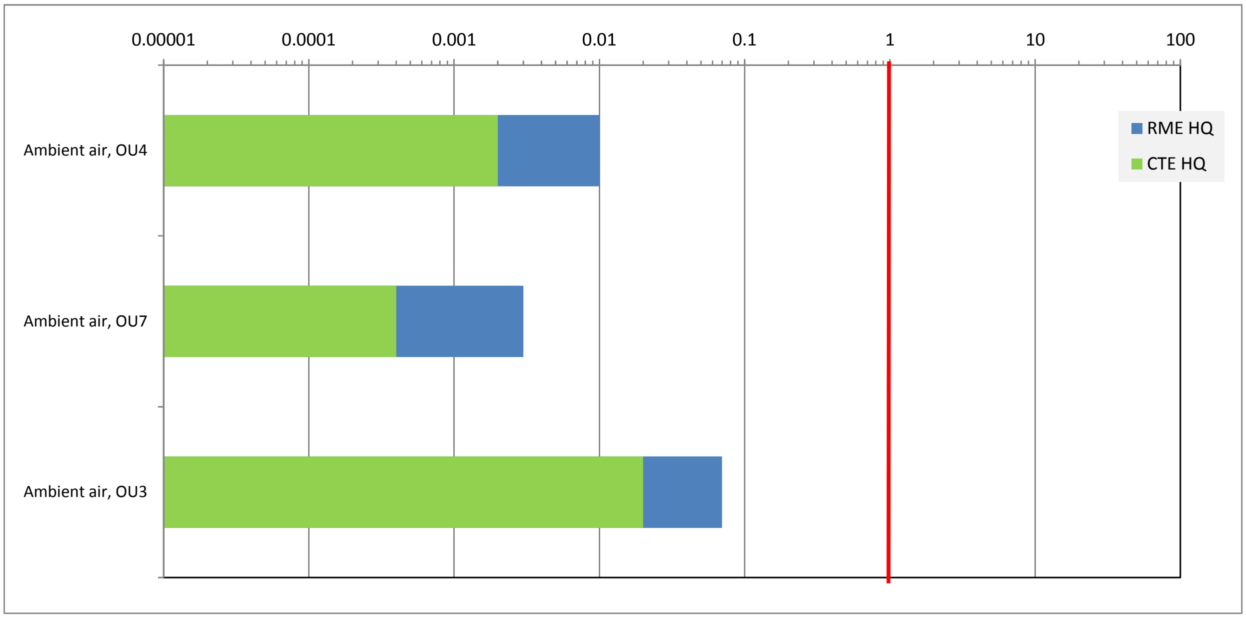
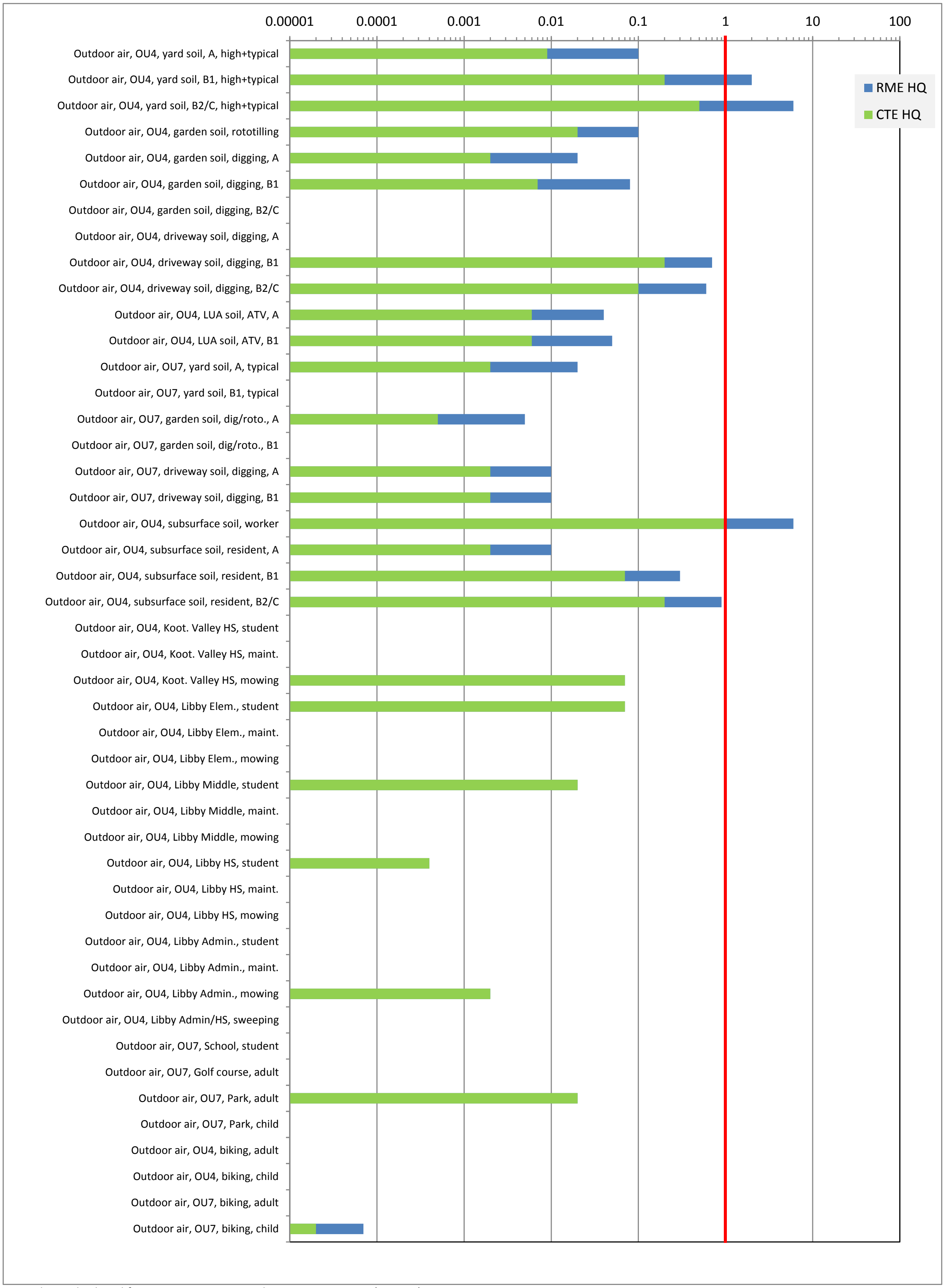


FIGURE 11-2. SUMMARY OF HQs FOR ALL SOIL DISTURBANCE EXPOSURE SCENARIOS (page 1 of 2)

Libby Asbestos Superfund Site



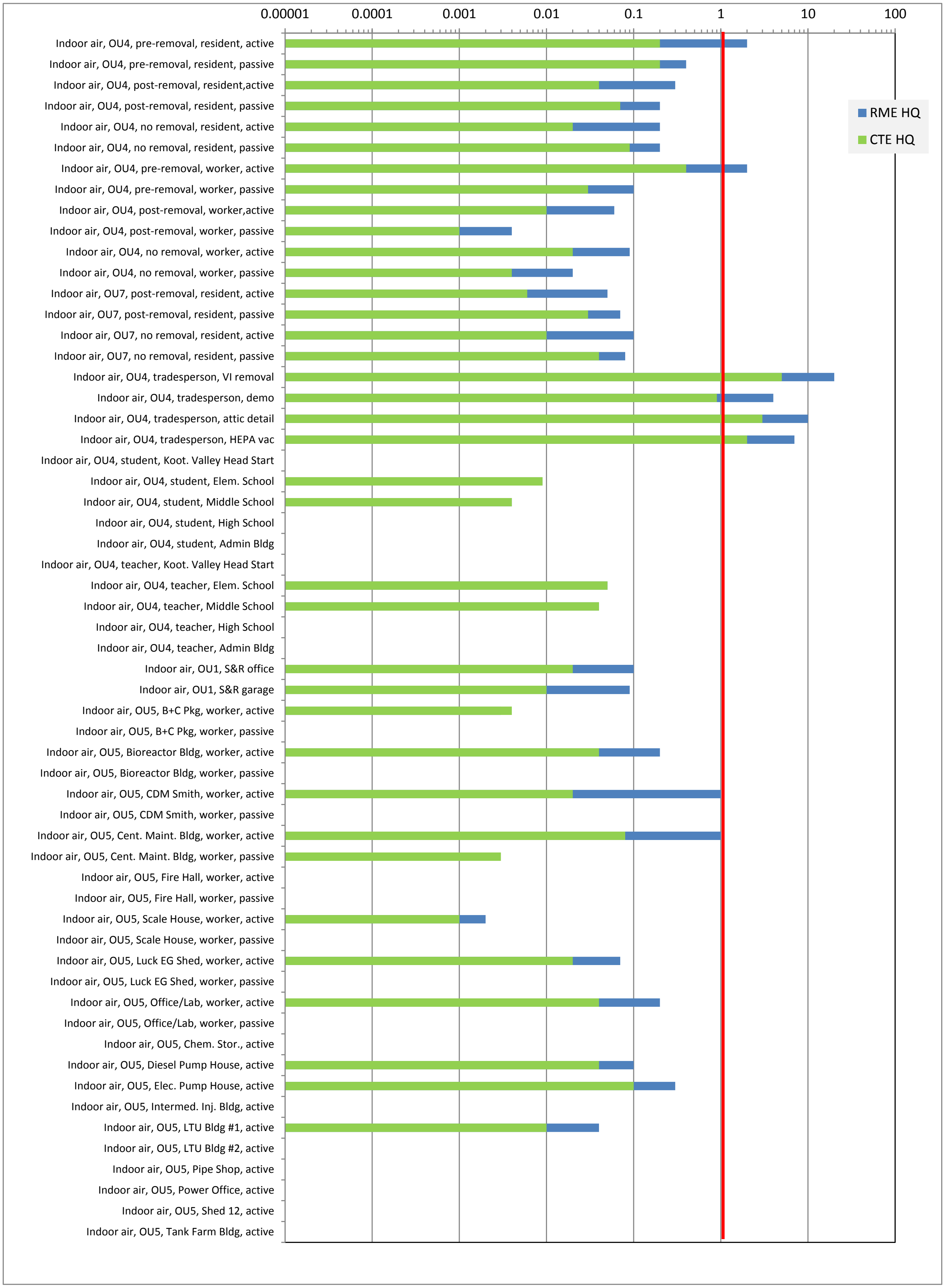
No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

FIGURE 11-2. SUMMARY OF HQs FOR ALL SOIL DISTURBANCE EXPOSURE SCENARIOS (page 2 of 2)
Libby Asbestos Superfund Site

No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

FIGURE 11-3. SUMMARY OF HQs FOR ALL INDOOR AIR EXPOSURE SCENARIOS

Libby Asbestos Superfund Site



No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

FIGURE 11-4. SUMMARY OF HQs FOR ALL WOOD-RELATED DISTURBANCE EXPOSURE SCENARIOS

Libby Asbestos Superfund Site

No bar is displayed for exposure scenarios where HQs were zero (EPC = 0).

TABLES

TABLE 2-1
Conceptual Site Model, Exposure Pathways and Populations
Libby Asbestos Superfund Site

Exposure Media	Exposure Locations	Operable Unit	Disturbance Description	Exposure Population[a]					
				Resident	Recreational Visitor	Teachers/ students	Worker		
							Indoor Worker	Tradesperson	Outdoor Worker
Outdoor air, ambient conditions	Outdoor	All	---	●	●	●	●	●	●
Outdoor air, during soil/duff disturbance activities	Parks	OU1, OU4, OU7	lawn/park maintenance						●
			park use		●				
	Road ROW	OU2, OU8	mowing/brush-hogging						●
	Kootenai River	OU2, OU3	hiking on trails/paths		●				
			fishing/boating		●				
	Mine Site, Rainy Creek	OU3	hiking, tresspassing		●				
	Forested Areas	OU3, OU4	hiking		●				
			building campfires		●				
			ATV riding		●				
			USFS forest maintenance						●
			cutting firelines						●
	Residential/Commercial Properties	OU2, OU4, OU7	yard work	●					●
			gardening	●					●
			playing on driveways	●					
			ATV riding in LUAs	●					
	Schools	OU4, OU7	outdoor maintenance						●
			playing on playgrounds			●			
	Bike Trails/Paths	OU4, OU5, OU7	riding bicycles		●				
	Roads	OU3, OU8	driving cars	●	●	●	●	●	●
	Motocross Track	OU5	motocross participant/spectator		●				
	Industrial Properties	OU5	site maintenance						●
	Railyard/Railroad Corridors	OU6	RR maintenance						●
Outdoor air, during tree bark disturbance activities	Forested Areas	OU3, OU4	local wood harvesting	●					
			commercial logging						●
			campfire burning		●				
			wildfire	●	●	●	●	●	●
	Landfills	OU4, OU7	woodchipping						●
Outdoor air, during woodchip/mulch disturbance activities	Residential/Commercial Properties	OU2, OU4, OU7	gardening/landscaping	●					●
	Woodchip Piles	OU5	pile maintenance						●
Indoor air, passive conditions	Residential/Commercial Properties	OU4, OU7	---	●			●		
	Industrial Properties	OU5	---				●		
	Schools	OU4, OU7	---			●			
Indoor air, during VI disturbance activities	Residential/Commercial Properties	OU4, OU7	attic use, routine property maintenance	●				●	
			construction/demolition					●	
Indoor air, during indoor dust disturbance activities	Residential/Commercial Properties	OU4, OU7	cleaning (sweeping, dusting, vacuuming)	●					
	Commercial/Industrial Buildings	OU1, OU5	general				●		
	Schools	OU4, OU7	general			●			
Indoor air, during woodstove ash disturbance activities	Residential/Commercial Properties	OU4, OU7	woodstove ash removal	●					

[a] Note that a given individual may be a member of several exposure populations. For example, an individual may live in OU7, work in OU4, and recreate in OU3. In this example, aspects of the exposure scenarios for a resident, indoor worker, and recreational visitor would apply to the individual. The cumulative assessment addresses cumulative exposures that span multiple exposure scenarios.

Notes:

ATV - all-terrain vehicle
LUAs - limited-use areas
OU - operable unit
ROW - right-of-way
USFS - United States Forest Service
VI - vermiculite insulation
RR - railroad

TABLE 2-2
Summary of ABS Investigations Performed at the Site
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU1	Summer 2013	Post-Construction ABS	Collection of personal ABS air samples during mowing and weed-trimming activities at the park	9 ABS air (6 mowing, 3 weed-trimming)
OU2	Summer 2012	Post-Construction ABS	Collection of personal ABS air samples during mowing along the Flyway right-of-way and while hiking along the Kootenai River	9 ABS air (3 mowing, 6 hiking)
OU3	Summer 2009	Phase III	Collection of personal ABS air samples during recreational activities in the forest (ATV-riding, hiking, campfire building/burning)	227 ABS air (6-8 sampling events for each of 11 areas)
OU3	Summer 2010 - 2011	Phase IV-A	Collection of personal ABS air samples while hiking along Rainy Creek	10 ABS air
OU3	Summer 2010 - 2011	Phase IV-A	Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually and with heavy equipment)	60 ABS air (5 sampling events for each of 3 areas)
OU3	Summer 2012	Phase V-A	Collection of personal ABS air samples during recreational activities in the Kootenai River	2 ABS air 4 sediment
OU3	Summer 2014	Pulaski Nature & Extent	Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually)	60 ABS air (3 sampling events)
OU4	Summer 2001	Phase 2, Scenario 4	Collection of personal ABS air samples during garden rototilling	2 ABS air
OU4	Summer 2005	SQAPP, Task 3	Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	169 ABS air 36 soil
OU4	Summer 2007, Spring 2008	2007-2008 OU4 Residential Outdoor ABS	Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	450 ABS air (1 sampling event in summer, 1 sampling event in spring) 225 soil
OU4	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while playing outside at schools	30 ABS air
OU4	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while mowing lawns at schools	15 ABS air
OU4	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while performing maintenance activities at schools (power-sweeping, digging, raking, and sweeping)	18 ABS air
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	120 ABS air (3 sampling events) 120 soil
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	60 ABS air (3 sampling events) 60 soil
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	62 ABS air (3 sampling events) 62 soil
OU4	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 5: Collection of personal ABS air samples while bicycling on paths/trails in Libby	90 ABS air (60 rider, 30 trailer)
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards (using 2 different ABS scripts)	80 ABS air (3 sampling events) 40 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 2: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards previously evaluated in 2010	31 ABS air (3 sampling events) 31 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 3: Collection of personal ABS air samples during mowing in residential yards pre- and post-irrigation	18 ABS air (3 sampling events) 18 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	Scenario 4: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards where curb-to-curb removal has been completed	31 ABS air (3 sampling events) 31 soil
OU4	Summer 2011	2011 Residential Outdoor ABS	LUA: Collection of personal ABS air samples during ATV riding in limited-use areas at residential properties	60 ABS air (3 sampling events, two riders per event) 30 soil

TABLE 2-2
Summary of ABS Investigations Performed at the Site
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances (cont.)

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU5	Summer/Fall 2008	Worker ABS	Collection of personal ABS air samples during outdoor worker activities (bulldozer operator, raking)	48 ABS air 462 soil
		MotoX ABS	Collection of personal and stationary ABS air samples during activities at the MotoX track	34 ABS air (24 rider, 10 spectator) 21 soil
		Recreational ABS	Collection of personal ABS air samples while bicycling on bike path in OU5	46 ABS air (39 rider, 7 trailer)
OU6	Summer 2008	BNSF ABS	Collection of personal and stationary ABS air samples during rail maintenance activities	46 ABS air (35 personal, 11 stationary)
OU7	Spring/Summer 2011	OU7 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	41 ABS air (1 sampling event in spring 1 sampling event in summer) 41 soil
			Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	38 ABS air (1 sampling event in spring, 1 sampling event in summer) 38 soil
			Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	40 ABS air (1 sampling event in spring, 1 sampling event in summer) 40 soil
			Scenario 4: Collection of personal ABS air samples while bicycling on paths/trails in Troy	40 ABS air (20 rider, 20 trailer)
OU8	Spring 2011, Summer 2010	OU8 Outdoor Worker ABS	Collection of equipment and stationary ABS air samples during road rotomilling activities	61 ABS air (10 equipment, 51 stationary)
			Collection of equipment ABS air samples during mowing and brush-hogging activities	14 ABS air
	Summer 2010	2010 OU4 Residential Outdoor ABS, Scenario 5	Collection of personal ABS air while driving on roads in Libby	20 ABS air (20 sampling events)
	Summer 2011	OU7 Residential Outdoor ABS	Collection of personal ABS air while driving on roads in Troy	20 ABS air (20 sampling events)

Panel B: ABS Studies During Disturbances of Wood-Related Materials

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU3	Summer 2010	2010 OU3 Phase IVA ABS	Collection of ABS air samples while performing activities as part of the USFS land management responsibilities, including maintenance of roads and trails, thinning of trees and vegetation, and surveying trees (i.e., stand examination).	90 ABS air (30 trail maintenance, 30 thinning trees, 30 stand exam)
	Summer 2010	2010 OU3 Phase IVA ABS	Collection of personal ABS air during wood harvesting at three locations in the forested area downwind (northeast) of the mine site (i.e., approximately 2 miles, 4 miles, and 8 miles from the mine site)	62 ABS air (30 driving, 6 cutting and hauling, 32 felling and limbing, 24 cutting and stacking)
	Summer 2012	2012 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, "hooking and skidding" felled trees to a central landing area, mechanical processing, milling, and site restoration of the landing area using a bulldozer -ABS area within one mile of mine (high source concentrations)	13 ABS air (3 hand felling, 5 skidding/hooking of timber, 2 site restoration, 1 mechanical processing, and 2 milling) 5 tree bark 5 duff
	Summer 2013	2013 Souse Gulch Wildfire Contingency Monitoring Plan Air	Collection of air samples to provide measured data on LA exposures of responding firefighters (both to the ground crews and the aircraft support pilot) and downwind LA concentrations in air during the fire.	18 ABS air
	Summer 2014	2014 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, "hooking and skidding" felled trees to a central landing area, mechanical processing, milling, cutting slabs pre-milling, and site restoration of the landing area using a bulldozer -ABS area about four miles from mine (lower source concentrations)	29 ABS air (3 hand felling, 4 skidding/hooking of timber, 2 site restoration, 4 mechanical processing, 8 milling and 8 cutting slabs pre-milling) 6 tree bark 6 duff
OU4	Summer 2011	2011 OU4 Miscellaneous ABS	Collection of ABS air samples from each of the two piles in OU5	15 ABS air (3 sampling events for each of the 5 woodchip material draws)
	Summer 2012	2012 OU4 ABS Woodstove Ash	Collection of air samples to measure LA concentrations in air during woodstove ash-removal activities	9 ABS air (3 events for each of 3 locations) 9 tree bark 9 ash

TABLE 2-2
Summary of ABS Investigations Performed at the Site
Libby Asbestos Superfund Site

Panel B: ABS Studies During Disturbances of Wood-Related Materials (cont.)

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU5	Fall 2007	Former Stimson Lumber Mill Site-Wood Chip Pilot Study	Collection of personal ABS air samples for the excavator operator and sampling personnel during the waste bark and wood chip pile test pit excavations	16 ABS air (12 woodchip piles, 4 waste bark piles)
OU7	Spring 2013	2013 Troy Landfill Activity-Based Sampling	Collection of ABS air samples during woodchipping of a woodwaste pile at the Lincoln County Landfill in Troy	6 ABS air

Panel C: Indoor ABS Studies

Operable Unit	Sampling Date	Investigation	Description	Samples Collected and Analyzed
OU1	Winter 2012	Clearance Sampling	Search and Rescue Building clearance samples	5 air samples
OU4	Summer 2001	Phase 2	Scenario 1 & 2: Collection of personal ABS air during active and passive residential/commercial behaviors	59 ABS air (16 passive, 43 active) 47 dust
			Scenario 3: Collection of personal ABS air during simulated tradesperson activities	17 ABS air
	Summer 2005	SQAPP, Task 2	Collection of personal ABS air samples during passive (no active) residential behaviors	29 ABS air (11 personal, 18 stationary) 34 dust
	Summer 2007 - Spring 2008	2007-2008 OU4 Residential Indoor ABS	Collection of personal ABS air samples during active and passive residential behaviors	642 ABS air (4 sampling rounds - 1 per season) 334 dust 162 soil
	Summer 2009	Libby Schools Indoor ABS	Collection of stationary ABS air samples inside schools	50 stationary air
	Various	Tradesperson Re-Analysis	Re-analysis of collected personal H&S samples of workers during interior removal activities (bulk removal, demolition, detailing attic, and wet wipe/HEPA vacuum)	17 H&S personal air
	Winter 2013, Summer 2013	2013 OU4 Residential Indoor ABS	Scenario 1: Collection of personal ABS air samples during active and passive residential behaviors at properties where a curb-to-curb soil removal has been completed	40 ABS air (1 sampling event in winter, 1 sampling event in summer) (20 active, 20 passive)
	Summer 2013		Scenario 2: Collection of personal ABS air samples during active and passive residential behaviors at properties evaluated in 2007/08	20 ABS air (10 active, 10 passive)
OU5	Winter 2007	Indoor Worker ABS	Collection of personal ABS air samples during active and passive worker behaviors inside occupied OU5 buildings	37 ABS air (28 active, 9 passive) 24 dust
			Collection of stationary ABS air samples inside vacant OU5 buildings	50 ABS air 70 dustfall
OU7	Spring, Summer 2011	OU7 Residential/Commercial Indoor ABS	Collection of personal ABS air samples during active and passive residential and commercial behaviors	80 ABS air (72 residential, 8 commercial) (1 sampling event in spring 1 sampling event in summer)

Notes:
ABS - activity-based sampling
BNSF - Burlington Northern and Santa Fe
H&S - health and safety
HEPA - high efficiency particulate air
LA - Libby amphibole asbestos
OU - operable unit
SQAPP - Supplemental Remedial Investigative Quality Assessment and Project Plan
USFS - United States Forest Service

TABLE 5-1
Summary Statistics For Ambient Air Monitoring Stations
Libby Asbestos Superfund Site

Station ID	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Libby (within community)					
L1	37	4	0.0000052	0.000079	0.000038
L2	30	6	0.0000089	0.000080	0.000038
L3	32	0	0	All ND	0.000038
L4	38	7	0.000011	0.00011	0.000038
L5	38	8	0.0000096	0.000079	0.000038
L6	36	3	0.0000063	0.00015	0.000038
L7	36	3	0.0000032	0.000040	0.000038
L8	83	7	0.0000032	0.000040	0.000038
L9	38	4	0.0000040	0.000040	0.000038
L10	32	2	0.0000024	0.000039	0.000038
L11	30	1	0.0000028	0.000085	0.000038
L12	52	6	0.0000067	0.000080	0.000038
L13	31	2	0.0000024	0.000038	0.000038
L14	38	0	0	All ND	0.000038
L15	16	1	0.0000025	0.000040	0.000038
L16	18	1	0.0000021	0.000037	0.000038
L17	17	0	0	All ND	0.000038
L18	18	3	0.000017	0.00023	0.000038
Libby (along transportation corridors)					
L20	18	0	0	All ND	0.000039
L21	60	4	0.0000031	0.000078	0.000039
L22	49	6	0.0000070	0.00012	0.000039
L23	46	13	0.000028	0.00028	0.000039
L24	18	2	0.0000043	0.000039	0.000039
L25	33	5	0.000012	0.00014	0.000039
L26	14	4	0.000013	0.000064	0.000038
OU3 (at mine site)					
A-1	4	0	0	All ND	0.00053
A-2	4	0	0	All ND	0.00053
A-3	4	0	0	All ND	0.00053
A-4	12	0	0	All ND	0.00053
A-5	12	4	0.00040	0.0026	0.00053
A-6	12	1	0.000043	0.00051	0.00053
A-7	4	0	0	All ND	0.00053
A-8	12	0	0	All ND	0.00056
A-9	8	3	0.00096	0.0056	0.00057
A-10	8	0	0	All ND	0.00056
A-11	8	2	0.00045	0.0026	0.00052
A-12	8	0	0	All ND	0.00053

TABLE 5-1
Summary Statistics For Ambient Air Monitoring Stations
Libby Asbestos Superfund Site

Station ID	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Troy (Zone 1)					
T1	35	2	0.0000032	0.000074	0.000039
T2	35	2	0.0000022	0.000038	0.000039
T11	35	1	0.0000011	0.000039	0.000039
T12	33	1	0.0000012	0.000039	0.000039
T21	30	2	0.0000027	0.000040	0.000039
Troy (Zone 2)					
T3	36	0	0	All ND	0.000039
T4	36	1	0.0000010	0.000037	0.000039
T5	35	1	0.00000080	0.000028	0.000044
T13	36	0	0	All ND	0.000039
T14	36	1	0.00000044	0.000016	0.000046
T15	36	0	0	All ND	0.000039
T22	30	3	0.0000080	0.00016	0.000045
Troy (Zone 3)					
T6	36	1	0.0000010	0.000036	0.000039
T16	35	0	0	All ND	0.000039
T23	27	2	0.0000030	0.000040	0.000039
Troy (Zone 4)					
T7	35	1	0.0000010	0.000036	0.000039
T17	36	0	0	All ND	0.000039
T24	30	1	0.0000013	0.000040	0.000039
Eureka, MT					
R1	32	0	0	All ND	0.000037
Helena, MT					
R2	39	4	0.0000054	0.000076	0.000038

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
ID - identification
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 5-2
Exposure Point Concentrations for Ambient Air
Libby Asbestos Superfund Site

Exposure Area	Number of Samples	Mean PCME LA Air Concentration (s/cc) Across Stations by Month												EPC
		January	February	March	April	May	June	July	August	September	October	November	December	Mean Across Months
Libby	858	0	0.0000032	0.0000047	0.0000035	0.0000084	0.0000076	0.0000082	0.000017	0.000016	0.0000048	0.00000095	0.00000018	**0.0000062**
Within community	620	0	0.0000014	0.0000023	0.0000018	0.0000066	0.0000075	0.0000083	0.000012	0.000011	0.0000062	0.00000064	0.00000022	**0.0000048**
Along transportation corridors	238	0	0.000011	0.000014	0.000010	0.000013	0.0000079	0.0000081	0.000026	0.000024	0.0000014	0.0000018	0	**0.0000098**
Troy	612	0.00000095	0.0000040	0.0000026	0.00000086	0.00000070	0.0000014	0.0000014	0	0.0000054	0.00000047	0	0	**0.0000015**
OU3, near mine site	96	--	--	--	--	--	--	0.000065	0.00054	0.00018	0	--	--	**0.00020**

-- = no samples collected in this month.

Notes:
EPC - exposure point concentration
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 5-3
Exposure Parameters For Ambient Air Exposure Scenarios
Libby Asbestos Superfund Site

Exposure Media	Exposure Location	Receptor Type	Parameter Type	Exposure Parameter/ Source: Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-Weighting Factor [TWF]**
Ambient Air	Libby/Troy	Resident	RME	6.9	[1] a.1	350	[2] b.1	50	[1] c.1	0.20
			CTE	1.6	[1] a.1	350	[2] b.1	25	[4] c.2	0.023
	OU3	Recreational Visitor	RME	8.0	[3] a.2	50	[3] b.2	50	[1] c.1	0.033
			CTE	8.0	[3] a.2	25	[3] b.3	25	[4] c.2	0.0082

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

[2] EPA. 1991. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: “Standard Default Exposure Factors”. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[3] Professional judgment using site-specific considerations.

[4] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day spent breathing ambient air are default values in EPA, 2011,Table 16-20. CTE is the 50th percentile and RME is the 95th percentile.

a.2 Assumes full-day excursion into forested areas surrounding OU3.

b) Exposure Frequency [EF]

b.1 Days/year at residence. Recommended default for residents in EPA 1991 (350 days/year is based on the assumption the resident spends a 2 week vacation each year away from residence).

b.2 Assumes recreational activities are performed every weekend (Saturday & Sunday) from April to September (25 weeks).

b.3 CTE is assumed to be 1/2 RME.

c) Exposure Duration [ED]

c.1 The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years.

c.2 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 5-4
Estimated Risks from Exposure to LA in Ambient Air
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Exposure Media	Receptor Population	Exposure Location	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)⁺	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, under ambient conditions	Resident	Libby	0.0000062	6.9	350	50	0.20	**2E-07**	**0.01**
		Within community	0.0000048	6.9	350	50	0.20	**2E-07**	**0.01**
		Along transportation corridors	0.0000098	6.9	350	50	0.20	**3E-07**	**0.02**
		Troy	0.0000015	6.9	350	50	0.20	**5E-08**	**0.003**
	Recreational visitor	OU3, mine site	0.00020	8	50	50	0.033	**1E-06**	**0.07**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Exposure Media	Receptor Population	Exposure Location	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)⁺	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, under ambient conditions	Resident	Libby	0.0000062	1.6	350	25	0.023	**2E-08**	**0.002**
		Within community	0.0000048	1.6	350	25	0.023	**2E-08**	**0.001**
		Along transportation corridors	0.0000098	1.6	350	25	0.023	**4E-08**	**0.002**
		Troy	0.0000015	1.6	350	25	0.023	**6E-09**	**0.0004**
	Recreational visitor	OU3, mine site	0.00020	8	25	25	0.0082	**3E-07**	**0.02**

⁺ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

CTE - central tendancy exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-1
Exposure Parameters During Residential/Commercial Soil Disturbance Activities in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Surface Soil Disturbances

Exposure Media	Receptor Type	Exposure Location	Parameter Type	Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Surface Soil/Duff Disturbance Activities	Resident	Yard	RME	6.6	[3] a.1	60	[2] b.1	50	[1] c.1	0.032
			CTE	2.2	[3] a.1	30	[2] b.1	25	[4] c.2	0.0027
		Garden (digging)	RME	3.3	[2] a.2	40	[2] b.2	50	[1] c.1	0.011
			CTE	1.1	[2] a.2	20	[2] b.2	25	[4] c.2	0.00090
		Garden (rototilling)	RME	2.0	[2] a.5	2	[2] b.5	50	[1] c.1	0.00033
			CTE	1.0	[2] a.5	1	[2] b.5	25	[4] c.2	0.000041
		Driveway	RME	2.0	[2] a.3	225	[2] b.3	15	[1] c.3	0.011
			CTE	0.9	[2] a.3	113	[2] b.3	15	[1] c.3	0.0025
		Limited-use Areas (LUAs)	RME	2.0	[2] a.4	20	[2] b.4	50	[1] c.1	0.0033
			CTE	1.0	[2] a.4	10	[2] b.4	25	[4] c.2	0.00041
	Outdoor Worker	Yard	RME	8.0	[2] a.6	100	[2] b.6	25	[5]	0.033
			CTE	8.0	[2] a.6	50	[2] b.6	15	[2]	0.010
		Garden (digging)	RME	2.0	[2] a.2	100	[2] b.6	25	[5]	0.008
			CTE	1.0	[2] a.2	50	[2] b.6	15	[2]	0.0012
		Garden (rototilling)	RME	2.0	[2] a.5	100	[2] b.6	25	[5]	0.0082
			CTE	1.0	[2] a.5	50	[2] b.6	15	[2]	0.0012

** TWF calculated as ET/24 · EF/365 · ED/70

Panel B: Subsurface Soil Disturbances

Exposure Media	Exposure Location	Receptor Type	Parameter Type	Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Subsurface Soil Disturbance Activities	Yard	Resident	RME	2.0	[2]	1	[2] b.7	50	[1] c.1	0.00016
			CTE	2.0	[2]	0.5	[2] b.7	25	[4] c.2	0.000041
		Outdoor Worker	RME	2.0	[2]	50	[2] b.8	25	[5]	0.0041
			CTE	2.0	[2]	25	[2] b.8	15	[2]	0.0012

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

[2] Professional judgment using site specific considerations.

[3] U.S. Bureau of Labor Statistics, American Time Use Survey (http://www.bls.gov/tus/).

[4] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

[5] EPA. 1991. RAGS, Volume 1, Supplemental Guidance. Standard Default Exposure Factors. OSWER Directive 9285.6-03

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day based on mean and 95th percentile for activity category 020501 (lawn, garden, and houseplant care), as derived from the raw data for years 2009-2013. [mean = 2.12, rounded to 2.2; 95th percentile = 6.56, rounded to 6.6]

a.2 Hours/day doing intensive gardening (digging) are based on professional judgment assuming 1/2 of total yard work time is spent gardening.

a.3 Hours/day spent playing on dirt (driveways) are EPA default values in EPA 2011[1], Tables 16-1, 16-38. Values are rounded for children < 21 years.

a.4 Hours/day riding ATV in LUAs are based on professional judgment. CTE assumes 1/2 RME value.

a.5 Assumed that 2 hours/day spent rototilling gardens. CTE assumes 1/2 RME value.

a.6 Assumed 8-hour workday; entire day is spent engaged in soil disturbance activities with half of the time in the yard and the other half in the garden.

a.7 Hours/day doing intensive gardening (digging and rototilling) are based on professional judgment assuming 1/2 of the work day is spent gardening. Half of the gardening time is assumed to be rototilling.

TABLE 6-1
Exposure Parameters During Residential/Commercial Soil Disturbance Activities in OU4 and OU7
Libby Asbestos Superfund Site

b) Exposure Frequency [EF]

b.1 Days/year performing yard work is based on professional judgment considering site specific conditions - assumes yard work will take place during warmer months (mainly between May and September) for 3 days per week for RME for a total of 60 days per year; CTE was assumed to be 1/2 RME value.

b.2 Days per year gardening is based on professional judgment considering site-specific conditions - assumes garden work will take place during warmer months mainly between May and September for 1 to 2 days per week (total 20 to 40 days per year).

b.3 Days/year are site-specific. Default residential exposure frequency estimate of 350 days/year was adjusted to account for days when releases due to soil disturbance activities were unlikely, either due to snow cover or high soil moisture content (i.e., November to March) (350 days - 126 days (18 weeks for 7 days per week) = 224 days, rounded to 225).

b.4 Days/year riding ATV in LUAs are based on professional judgment. CTE assumes 1/2 RME value.

b.5 RME assumes rototilling is performed twice per year (at the beginning and end of the growing season). CTE assumes rototilling is only performed one time per year.

b.6 Days/year performing yard work is based on professional judgment considering site specific conditions - assumes yard work will take place during warmer months mainly between May and September for 5 days per week for RME for a total of 100 days per year; CTE was assumed to be 1/2 RME value.

b.7 Assumes that deeper digging (>1 to 3+ feet), such as digging a hole for a tree, occurs once per year for RME; CTE was assumed to be 1/2 RME value.

b.8 Assumes that deeper digging (>1 to 3+ feet), such as digging a hole for a sewer line or septic tank, during warmer months (mainly between May and September) for approximately 2-3 days per week for RME for a total of 50 days per year; CTE was assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years.

c.2 ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

c.3 Years spent playing on dirt driveways are based on EPA default values in EPA 2011, Tables 16-1, 16-38. Values are rounded for children < 21 years. This scenario assumes that toddlers through teenagers play on driveways. Activities vary according to age group from playing in the dirt, to riding big wheels or playing games like basketball.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
ATV - all-terrain vehicle
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
LUA - limited use area
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-2
Summary Statistics for Outdoor ABS Studies During Disturbances of Residential/Commercial Soils
Libby Asbestos Superfund Site

Panel A: Yard Soil Disturbances

LA Soil Concentration+	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
OU4					
High intensity ABS script					
Bin A	251	115	0.0040	0.20	0.0050
Bin B1	221	155	0.061	8.3	0.015
Bin B2	31	27	0.25	5.8	0.032
Bin C	7	5	0.039	0.19	0.0061
Bin B2/C	38	32	0.21	5.8	0.028
Typical intensity ABS script					
Bin A	110	15	0.00011	0.0029	0.0014
Bin B1	72	21	0.0024	0.077	0.0014
Bin B2	7	4	0.0080	0.044	0.00061
Bin C	--	--	--	--	--
Bin B2/C	7	4	0.0080	0.044	0.00061
OU7					
Typical intensity ABS script*					
Bin A	40	5	0.000062	0.0014	0.00022
Bin B1	1	0	0	All ND	0.00022

Panel B: Garden Soil Disturbances

LA Soil Concentration+	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
OU4: Digging					
Bin A	36	5	0.00020	0.0029	0.0016
Bin B1	21	5	0.00066	0.0039	0.0056
Bin B2	2	0	0	All ND	0.0030
Bin C	1	0	0	All ND	0.0029
Bin B2/C	3	0	0	All ND	0.0030
OU4: Rototilling					
Bin B1	2	2	0.039	0.057	0.0036
OU7: Digging & Rototilling					
Bin A	37	3	0.000023	0.00040	0.00023
Bin B1	1	0	0	All ND	0.00022

TABLE 6-2
Summary Statistics for Outdoor ABS Studies During Disturbances of Residential/Commercial Soils
Libby Asbestos Superfund Site

Panel C: Driveway Soil Disturbances

LA Soil Concentration+	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
OU4					
Bin A	44	0	0	All ND	0.0039
Bin B1	15	2	0.0057	0.076	0.0043
Bin B2	2	1	0.0075	0.015	0.0034
Bin C	1	0	0	All ND	0.0039
Bin B2/C	3	1	0.0050	0.015	0.0036
OU7					
Bin A	35	5	0.000079	0.0015	0.00023
Bin B1	5	2	0.000085	0.00021	0.00021

Panel D: OU4 Limited Use Area Soil Disturbances

LA Soil Concentration+	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)++		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Bin A	40	14	0.0012	0.0069	0.0022
Bin B1	20	8	0.0014	0.0062	0.0017

+PLM-VE LA Result:

Bin A = ND (non-detect)

Bin B1 = Tr (trace; <0.2%)

Bin B2 = <1%

Bin C = ≥1%

++ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

*No high intensity ABS script samples were collected.

Notes:

ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase contrast microscopy-equivalent
PLM-VE - polarized light microscopy - visual area estimation
s/cc - structures per cubic centimeter

TABLE 6-3a
Estimated Residential Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Exposure Scenario & Soil Concentration[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.3	60	50	0.0015	**1E-06**	**0.07**
		typical intensity	0.00011	6.3	60	50	0.031	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Bin B1	**high intensity**	0.061	0.3	60	50	0.0015	**2E-05**	**1**
		typical intensity	0.0024	6.3	60	50	0.031	**1E-05**	**0.8**
							TOTAL	**3E-05**	**2**
	Bin B2/C	**high intensity**	0.21	0.3	60	50	0.0015	**5E-05**	**3**
		typical intensity	0.0080	6.3	60	50	0.031	**4E-05**	**3**
							TOTAL	**9E-05**	**6**
	Gardens (Rototilling)								
	Bin B1	---	0.039	2	2	50	0.00033	**2E-06**	**0.1**
	Gardens (Digging)								
	Bin A	---	0.00020	3.3	40	50	0.011	**4E-07**	**0.02**
	Bin B1	---	0.00066	3.3	40	50	0.011	**1E-06**	**0.08**
	Bin B2/C	---	0	3.3	40	50	0.011	**0E+00**	**0**
	Driveway (Playing & Digging)								
	Bin A	---	0	2	225	15	0.011	**0E+00**	**0**
	Bin B1	---	0.0057	2	225	15	0.011	**1E-05**	**0.7**
	Bin B2/C	---	0.0050	2	225	15	0.011	**9E-06**	**0.6**
	LUAs (ATV-riding)								
	Bin A	---	0.0012	2	20	50	0.0033	**7E-07**	**0.04**
	Bin B1	---	0.0014	2	20	50	0.0033	**8E-07**	**0.05**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	6.6	60	50	0.032	**3E-07**	**0.02**
	Bin B1	**typical intensity**	0	6.6	60	50	0.032	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A	---	0.000023	5.3	42	50	0.018	**7E-08**	**0.005**
	Bin B1	---	0	5.3	42	50	0.018	**0E+00**	**0**
	Residential, Outdoor Driveway (Playing & Digging)								
	Bin A	---	0.000079	2	225	15	0.011	**1E-07**	**0.01**
	Bin B1	---	0.000085	2	225	15	0.011	**2E-07**	**0.01**

TABLE 6-3a
Estimated Residential Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Exposure Scenario & Soil Concentration[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.1	30	25	0.00012	**8E-08**	**0.005**
		typical intensity	0.00011	2.1	30	25	0.0026	**5E-08**	**0.003**
							TOTAL	**1E-07**	**0.008**
	Bin B1	**high intensity**	0.061	0.1	30	25	0.00012	**1E-06**	**0.08**
		typical intensity	0.0024	2.1	30	25	0.0026	**1E-06**	**0.07**
							TOTAL	**2E-06**	**0.2**
	Bin B2/C	**high intensity**	0.21	0.1	30	25	0.00012	**4E-06**	**0.3**
		typical intensity	0.0080	2.1	30	25	0.0026	**3E-06**	**0.2**
							TOTAL	**8E-06**	**0.5**
	Gardens (Rototilling)								
	Bin B1	---	0.039	1	1	25	0.000041	**3E-07**	**0.02**
	Gardens (Digging)								
	Bin A	---	0.00020	1.1	20	25	0.00090	**3E-08**	**0.002**
	Bin B1	---	0.00066	1.1	20	25	0.00090	**1E-07**	**0.007**
	Bin B2/C	---	0	1.1	20	25	0.00090	**0E+00**	**0**
	Driveway (Playing & Digging)								
	Bin A	---	0	0.9	113	15	0.0025	**0E+00**	**0**
	Bin B1	---	0.0057	0.9	113	15	0.0025	**2E-06**	**0.2**
	Bin B2/C	---	0.0050	0.9	113	15	0.0025	**2E-06**	**0.1**
	LUAs (ATV-riding)								
	Bin A	---	0.0012	1	10	25	0.00041	**8E-08**	**0.006**
	Bin B1	---	0.0014	1	10	25	0.00041	**1E-07**	**0.006**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	2.2	30	25	0.0027	**3E-08**	**0.002**
	Bin B1	**typical intensity**	0	2.2	30	25	0.0027	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A	---	0.000023	2.1	21	25	0.0018	**7E-09**	**0.0005**
	Bin B1	---	0	2.1	21	25	0.0018	**0E+00**	**0**
	Residential, Outdoor Driveway (Playing & Digging)								
	Bin A	---	0.000079	0.9	113	15	0.0025	**3E-08**	**0.002**
	Bin B1	---	0.000085	0.9	113	15	0.0025	**4E-08**	**0.002**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4).
[++] Exposure time and frequency have been summed because the EPC is based on a combination of the activities.

[1] PLM-VE Bin:
A - ND (non-detect)
B1 - Tr (trace; <0.2%)
B2 - <1%
C - ≥1%

Notes:
ABS - activity-based sampling
ATV - all- terrain vehicle
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
LUA - limited use areas
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-3b
Estimated Outdoor Worker Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Expsoure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.4	100	25	0.0016	**1E-06**	**0.07**
		typical intensity	0.00011	7.6	100	25	0.031	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Bin B1	**high intensity**	0.061	0.4	100	25	0.0016	**2E-05**	**1**
		typical intensity	0.0024	7.6	100	25	0.031	**1E-05**	**0.8**
							TOTAL	**3E-05**	**2**
	Bin B2/C	**high intensity**	0.21	0.4	100	25	0.0016	**6E-05**	**4**
		typical intensity	0.0080	7.6	100	25	0.031	**4E-05**	**3**
							TOTAL	**1E-04**	**7**
	Gardens (Rototilling)								
	Bin B1	---	0.039	2	100	25	0.008	**5E-05**	**4**
	Gardens (Digging)								
	Bin A	---	0.00020	2	100	25	0.008	**3E-07**	**0.02**
	Bin B1	---	0.00066	2	100	25	0.008	**9E-07**	**0.06**
	Bin B2/C	---	0	2	100	25	0.008	**0E+00**	**0**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	8	100	25	0.033	**3E-07**	**0.02**
	Bin B1	**typical intensity**	0	8	100	25	0.033	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A		0.000023	4	100	25	0.016	**6E-08**	**0.004**
	Bin B1	---	0	4	100	25	0.016	**0E+00**	**0**

TABLE 6-3b
Estimated Outdoor Worker Risks from Exposure to LA During Disturbances of Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Expsoure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	**Yards (Mowing, Raking, Digging)**								
	Bin A	**high intensity**	0.0040	0.4	50	15	0.00049	**3E-07**	**0.02**
		typical intensity	0.00011	7.6	50	15	0.0093	**2E-07**	**0.01**
							TOTAL	**5E-07**	**0.03**
	Bin B1	**high intensity**	0.061	0.4	50	15	0.00049	**5E-06**	**0.3**
		typical intensity	0.0024	7.6	50	15	0.0093	**4E-06**	**0.2**
							TOTAL	**9E-06**	**0.5**
	Bin B2/C	**high intensity**	0.21	0.4	50	15	0.00049	**2E-05**	**1**
		typical intensity	0.0080	7.6	50	15	0.0093	**1E-05**	**0.8**
							TOTAL	**3E-05**	**2**
	Gardens (Rototilling)								
	Bin B1	---	0.039	1	50	15	0.0012	**8E-06**	**0.5**
	Gardens (Digging)								
	Bin A	---	0.00020	1	50	15	0.0012	**4E-08**	**0.003**
	Bin B1	---	0.00066	1	50	15	0.0012	**1E-07**	**0.009**
	Bin B2/C	---	0	1	50	15	0.0012	**0E+00**	**0**
OU7	**Yards (Mowing, Raking, Digging)**								
	Bin A	**typical intensity**	0.000062	4	50	15	0.0049	**5E-08**	**0.003**
	Bin B1	**typical intensity**	0	4	50	15	0.0049	**0E+00**	**0**
	Residential, Outdoor Gardens (Digging & Rototilling)[++]								
	Bin A		0.000023	2	50	15	0.0024	**9E-09**	**0.0006**
	Bin B1	---	0	2	50	15	0.0024	**0E+00**	**0**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[++] Exposure time has been summed because the EPC is based on a combination of the activities.

[1] PLM-VE Bin:
A - ND
B1 - Tr
B2 - <1
C - ≥ 1

Notes:
ABS - activity-based sampling
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-4

Nature of Surface Soil Materials Left in Place
Libby Asbestos Superfund Site

Soil Condition	Properties with a Soil Removal									Properties without a Soil Removal					
	SUA		CUA			LUA				SUA		CUA		LUA	
	2003-2013	2014 - present	2003-2006	2007-2013	2014 - present	2003-2006	2006-2010	2011-2013	2014 - present	2003-2013	2014 - present	2003-2013	2014 - present	2003-2013	2014 - present
Topsoil Fill Material Bin A (ND)															
Bin A (ND)	Vis -		Vis - or Vis +	Vis -		Vis - or Vis +	Vis -	Vis - or low Vis +		Vis -		Vis - or Vis +		Vis - or Vis +	
Bin B1 (Trace)		**			**			Vis - or low Vis +		Vis -	**	Vis - or Vis +	**	Vis - or Vis +	
Bin B2 (<1%)								Vis - or low Vis +		Vis -		Vis - or Vis +		Vis - or Vis +	
Bin C (≥1%)															

[white box] condition is not expected to be present
[grey box] condition may be present

**Trace levels may be present in less than 25% of the total area;
where: total area = SUA + CUA + SS + SB

Notes:

CUA - common-use area (e.g., yard)
LUA - limited-use area (e.g., pasture, maintained/mowed fields)
ND - non-detect
PLM-VE - polarized light microscopy - equivalent
SB - secondary building (e.g., soil floor of a garage or shed)
SS - secondary structure (e.g., unpaved carport or lean-to)
SUA - specific-use area (e.g., garden, flowerbed, unpaved driveway, play area)
Vis - - no visible vermiculite present
Vis + - visible vermiculite present
% - percent
< - less than
≥ - greater than or equal

PLM-VE Bin:
A - ND (non-detect)
B1 - Tr (trace; <0.2%)
B2 - <1%
C - ≥1%

TABLE 6-5
Screening Level Risk Estimates from Exposure to LA During Disturbances of Subsurface Soil at Properties in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Receptor Type	Soil Concentration[1]	Yard ABS Script	EPC: Mean Air Conc. (PCME LA s/cc)[+]	Exposure Parameters: ET (hours/ day)	EF (days/ year)[++]	ED (years)	TWF	Cancer Risk	Non-cancer HQ
OU4/OU7	Outdoor Worker	Bin A	digging, high intensity	0.0053	2	32.5	25	0.0027	**2E-06**	**0.2**
		Bin B1	digging, high intensity	0.16	2	7.5	25	0.00061	**2E-05**	**1**
		Bin B2/C	digging, high intensity	0.52	2	10	25	0.00082	**7E-05**	**5**
								TOTAL	**9E-05**	**6**
	Resident	Bin A	digging, high intensity	0.0053	2	1	50	0.00016	**1E-07**	**0.01**
		Bin B1	digging, high intensity	0.16	2	1	50	0.00016	**4E-06**	**0.3**
		Bin B2/C	digging, high intensity	0.52	2	1	50	0.00016	**1E-05**	**0.9**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Receptor Type	Soil Concentration[1]	Yard ABS Script	EPC: Mean Air Conc. (PCME LA s/cc)[+]	Exposure Parameters: ET (hours/ day)	EF (days/ year)[++]	ED (years)	TWF	Cancer Risk	Non-cancer HQ
OU4/OU7	Outdoor Worker	Bin A	digging, high intensity	0.0053	2	16.25	15	0.00080	**7E-07**	**0.05**
		Bin B1	digging, high intensity	0.16	2	3.75	15	0.00018	**5E-06**	**0.3**
		Bin B2/C	digging, high intensity	0.52	2	5	15	0.00024	**2E-05**	**1**
								TOTAL	**3E-05**	**1**
	Resident	Bin A	digging, high intensity	0.0053	2	0.5	25	0.000041	**4E-08**	**0.002**
		Bin B1	digging, high intensity	0.16	2	0.5	25	0.000041	**1E-06**	**0.07**
		Bin B2/C	digging, high intensity	0.52	2	0.5	25	0.000041	**4E-06**	**0.2**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[++] The total exposure frequency for the worker has been allocated to the various soil conditions according to the assumed frequency each condition is expected to be encountered.

[1] PLM-VE Bin:
A - ND
B1 - Tr
B2 - <1
C - ≥ 1

Notes:
ABS - activity-based sampling
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-6
Exposure Parameters During Soil Disturbances at Schools and Parks in OU4 and OU7
Libby Asbestos Superfund Site

Exposure Media	Operable Unit	Exposure Location	Receptor Type	Parameter Type	Exposure Parameter [1]						
					Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
					Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	OU4	Kootenai Valley Head Start	Student	---[b]	0.5	[1]	128	[1]	2	[1]	0.00021
			Maintenance Worker	---[b]	1.0	[1]	128	[1]	25	[1]	0.0052
		Libby Elementary School	Student	---[b]	2.0	[1]	180	[1]	6	[1]	0.0035
			Maintenance Worker	---[b]	1.5	[1]	260	[1]	25	[1]	0.016
		Libby Middle School	Student	---[b]	1.6	[1]	90	[1]	3	[1]	0.00070
			Maintenance Worker	---[b]	0.5	[1]	260	[1]	25	[1]	0.0053
		Libby High School	Student	---[b]	0.67	[1]	45	[1]	4	[1]	0.00020
			Maintenance Worker	---[b]	1.0	[1]	260	[1]	25	[1]	0.011
		Libby Admin. Building	Student [a]	---[b]	0.75	[1]	180	[1]	6	[1]	0.0013
			Maintenance Worker	---[b]	1.5	[1]	260	[1]	25	[1]	0.016
		All Schools	Lawn Mower	---[b]	10.0	[1]	22	[1]	25	[1]	0.0090
		Libby High School, Libby Admin. Bldg.	Power Sweeper	RME	2.0	[1]	22	[1]	25	[1]	0.0018
		Cabinet View Country Club	Maintenance Worker	RME	8.0	[2]	100	[2]	15	[2]	0.020
	OU7	Morrison Elementary School	Student	RME	2.0	[3]	180	[3]	6	[3]	0.0035
		Timberbeast Disc Golf Course	Recreational Visitor (adult)	RME	5.0	[4]	48	[5]	50	[6]	0.020
		Roosevelt Park, Ball Fields	Recreational Visitor (adult)	RME	5.0	[4]	48	[5]	50	[6]	0.020
		Roosevelt Park, Playground	Recreational Visitor (child)	RME	10.7	[4]	48	[5]	10	[4]	0.0084

** TWF calculated as ET/24 · EF/365 · ED/70

[a] Classes are held in the Libby Administration Building

[b] The basis (RME/CTE) of the exposure parameters provided by school administrators was not specified.

Source Citations:

[1] All OU4 exposure parameters are based on interviews with school administrators at each school. Outdoor exposure assumptions were developed to be representative of the entire year, which includes extreme variations in weather.

[2] Based on professional judgment; CTE exposure frequency is assumed to be 1/2 RME.

[3] Assumed to be equal to Libby Elementary School.

[4] Hours/day spent at parks or golf courses for based on in EPA 2011, Table 16-20. Hours/day spent at parks for children <11 years in age in EPA 2011, Table 16-19. RME is 95th percentile (rounded), CTE is 50th percentile (rounded).

[5] Assumes recreational activities occur twice per week for RME from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (24 weeks for 2 days per week (48 days) for RME and 1 day per week for CTE (24 days).

[6] Assumed to be a local resident. The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years.

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

References:

EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

TABLE 6-7
Summary Statistics for Outdoor ABS Air Samples at Schools and Parks in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: OU4 Schools

School Building	ABS Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
Kootenai Valley Head Start	Student	6	0	0	All ND	0.0066
	Maintenance Worker	3	0	0	All ND	0.0018
	Lawn Mower	3	1	0.00074	0.0022	0.0025
Libby Elementary School	Student	9	2	0.0019	0.016	0.0067
	Maintenance Worker	3	0	0	All ND	0.0029
	Lawn Mower	3	0	0	All ND	0.0031
Libby Middle School	Student	6	2	0.0020	0.0080	0.0054
	Maintenance Worker	3	0	0	All ND	0.0026
	Lawn Mower	3	0	0	All ND	0.0023
Libby High School	Student	6	1	0.00017	0.0010	0.0022
	Maintenance Worker	3	0	0	All ND	0.0028
	Lawn Mower	3	0	0	All ND	0.0017
Libby Public Schools, Admin Building	Student	3	0	0	All ND	0.0028
	Maintenance Worker	3	0	0	All ND	0.0027
	Lawn Mower	3	1	0.000019	0.000056	0.0019
Libby High School & Admin Building	Power Sweeper	3	0	0	All ND	0.0061

Panel B: OU7 Schools and Parks

Location	ABS Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
Morrison Elementary School	Student	13	0	0	All ND	0.00022
Timber Beast Disk Golf Course	Recreational, adult	12	0	0	All ND	0.00022
Roosevelt Park, ball fields	Recreational, adult	8	2	0.00011	0.00064	0.00022
Roosevelt Park, playground	Recreational, child	7	0	0	All ND	0.00022

Panel C: OU4 Golf Course

Location	ABS Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
Cabinet View Country Club	Course maintenance worker	7	3	0.00056	0.0020	0.00096

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 6-8
Estimated Risks from Exposure to LA During Disturbances of Soils at Schools and Parks
Libby Asbestos Superfund Site

Operable Unit	Exposure Location	Receptor Type	EPC Mean Air Conc. (PCME LA s/cc)+	Exposure Parameters ET (hours/day)	EF (days/year)	ED (years)	TWF	Cancer Risk	Non-cancer HQ
OU4	Kootenai Valley Head Start	Student	0	0.5	128	2	0.00021	**0E+00**	**0**
		Maintenance Worker	0	1.0	128	25	0.0052	**0E+00**	**0**
		Lawn Mower	0.00074	10	22	25	0.0090	**1E-06**	**0.07**
	Libby Elementary School	Student	0.0019	2.0	180	6	0.0035	**1E-06**	**0.07**
		Maintenance Worker	0	1.5	260	25	0.016	**0E+00**	**0**
		Lawn Mower	0	10	22	25	0.0090	**0E+00**	**0**
	Libby Middle School	Student	0.0020	1.6	90	3	0.00070	**2E-07**	**0.02**
		Maintenance Worker	0	0.5	260	25	0.0053	**0E+00**	**0**
		Lawn Mower	0	10	22	25	0.0090	**0E+00**	**0**
	Libby High School	Student	0.00017	0.67	45	4	0.00020	**6E-09**	**0.0004**
		Maintenance Worker	0	1.0	260	25	0.011	**0E+00**	**0**
		Lawn Mower	0	10	22	25	0.0090	**0E+00**	**0**
	Libby Admin. Building	Student	0	0.75	180	6	0.0013	**0E+00**	**0**
		Maintenance Worker	0	1.5	260	25	0.016	**0E+00**	**0**
		Lawn Mower	0.000019	10	22	25	0.0090	**3E-08**	**0.002**
	Libby High School and Libby Admin Building	Power Sweeper	0	2.0	22	25	0.0018	**0E+00**	**0**
	Cabinet View Country Club	Maintenance Worker	0.00056	8.0	100	15	0.020	**2E-06**	**0.1**
OU7	Morrison Elementary School	Student	0	2.0	180	6	0.0035	**0E+00**	**0**
	Timber Beast Disk Golf Course	Recreational Visitor, adult	0	5.0	48	50	0.020	**0E+00**	**0**
	Roosevelt Park, ball fields	Recreational Visitor, adult	0.00011	5.0	48	50	0.020	**4E-07**	**0.02**
	Roosevelt Park, playground	Recreational Visitor, child	0	10.7	48	10	0.0084	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-9
Exposure Parameters for Outdoor Air During Recreational Activities in OU4 and OU7
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Exposure Location	Exposure Scenario	Parameter Type	Exposure Parameter / Source: Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-Weighting Factor [TWF]**
Outdoor Air During Soil/Duff Disturbance Activities	Recreational Visitor	OU4	Biking on Trails (as adult rider)	RME	2	2 [a.1]	90	2 [b.1]	50	1,2 [c.1]	0.015
				CTE	1	2 [a.2]	45	2 [b.2]	25	2,5 [c.1]	0.0018
			Biking on Trails (as child in trailer)	RME	2	2 [a.1]	90	2 [b.1]	5	1 [c.2]	0.0015
				CTE	1	2 [a.2]	45	2 [b.2]	5	1[c.2]	0.00037
		OU7	Biking on Trails (as adult rider)	RME	0.75	3 [a.1]	90	2 [b.1]	50	1,2 [c.1]	0.0055
				CTE	0.38	3 [a.2]	45	2 [b.2]	25	2,5 [c.1]	0.00069
			Biking on Trails (as child in trailer)	RME	0.75	3 [a.1]	90	2 [b.1]	5	1 [c.2]	0.00055
				CTE	0.38	3 [a.2]	45	2 [b.2]	5	1 [c.2]	0.00014

** TWF calculated as ET/24 · EF/365 · ED/70

Source Notes:

[1] EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.
[2] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely participants and assumptions reflect this.
[3] Professional judgment using site specific considerations; adjusted based on Troy versus Libby city size.
[4] EPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.
[5] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

a) Exposure Time [ET]

a.1 Hours/day biking are based on professional judgment. Because Troy city extent is smaller than Libby, time spent biking in Troy is assumed to be less than time spent biking in Libby.
a.2 Hours/day for CTE assumed to be 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Assumes biking on trails occurs in the area from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (90 days per year) for RME and 1/2 the RME value for CTE (45 days). SAP/QAPP 2010.
b.2 Days/year for CTE assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 Assumed to be a local resident. The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.
c.2 Default age group (1 to 6 years) for evaluation of exposure to young children.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF -exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
SAP/QAPP - sampling and analysis plan/quality assurance project plan
TWF - time-weighting factor

TABLE 6-10
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils on Bike Paths and Trails
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Sector	ABS Sample Type	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
					Mean	Maximum Detect	
OU4	Sector A	Adult Rider	20	0	0	All ND	0.0033
		Inside Trailer	10	0	0	All ND	0.0082
	Sector B	Adult Rider	20	0	0	All ND	0.0035
		Inside Trailer	10	0	0	All ND	0.0085
	Sector C	Adult Rider	20	0	0	All ND	0.0035
		Inside Trailer	10	0	0	All ND	0.0091
OU7	---	Adult Rider	20	0	0	All ND	0.00022
		Inside Trailer	20	1	0.000011	0.00022	0.00022

Panel B: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Sector	Receptor Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Sector A-C	Adult Rider	0	2	90	50	0.015	**0E+00**	**0**
		Inside Trailer	0	2	90	5	0.0015	**0E+00**	**0**
OU7	---	Adult Rider	0	0.75	90	50	0.0055	**0E+00**	**0**
		Inside Trailer	0.000011	0.75	90	5	0.00055	**1E-09**	**0.00007**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Sector	Receptor Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Sector A-C	Adult Rider	0	1	45	25	0.0018	**0E+00**	**0**
		Inside Trailer	0	1	45	5	0.00037	**0E+00**	**0**
OU7	---	Adult Rider	0	0.38	45	25	0.00070	**0E+00**	**0**
		Inside Trailer	0.000011	0.38	45	5	0.00014	**3E-10**	**0.00002**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-11
Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU1
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Outdoor Worker (Park Maintenance Worker)	Mowing	RME	6	[1] a.1	13	[1] b.1	25	[1] c.1	0.0032
			CTE	6	[1] a.1	6	[1] b.2	7	[2] c.2	0.00041
		Weed-trimming	RME	1	[1] a.2	13	[1] b.1	25	[1] c.1	0.00053
			CTE	1	[1] a.2	6	[1] b.2	7	[2] c.2	0.000068

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Professional judgment using site specific considerations.

[2] EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

Source Notes:

a) Exposure Time [ET]

a.1 The time required to mow the park is based on the area of the park (≈12 acres) assuming that 2 acres per hour are mowed.

a.2 The time spent weed trimming is based on the area of the park that cannot be accessed by mowers which is a fraction of the total area.

b) Exposure Frequency [EF]

b.1 Assumes that workers mow the park every other week during spring and summer (13 days per year).

b.2 Days/year for CTE assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 ED for RME is based on professional judgment.

c.2 ED is recommended mean value for workers in EPA 2011[2].

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-12
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU1
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU1	Mowing	6	1	0.00044	0.0026	0.0028
	Weed-trimming	3	0	0	All ND	0.011

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing	0.00044	6	13	25	0.0032	**2E-07**	**0.02**
	Weed-trimming	0	1	13	25	0.00053	**0E+00**	**0**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing	0.00044	6	6	7	0.00041	**3E-08**	**0.002**
	Weed-trimming	0	1	6	7	0.000068	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-13
Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU2
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Exposure Scenario	Parameter Type	Exposure Parameters						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Outdoor Worker (MDT Maintenance Worker)	ROW Maintenance (Mowing)	RME	1	[1] a.1	5	[1 b.1	15	[1] c.1	0.00012
			CTE	1	[1] a.1	5	[1] b.1	7	[2] c.2	0.000057
	Recreational Visitor (Hiking)	Hiking along Kootenai River	RME	2	[1] a.2	10	[1] b.2	50	[2] c.3	0.0016
			CTE	1	[1] a.3	5	[1] b.3	25	[3] c.3	0.00020

** TWF calculated as ET/24 · EF/365 · ED/70

<u>**Source Citations:**</u>

[1] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely the participants and assumptions reflect this.

[2] EPA 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

[3] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

<u>**Source Notes:**</u>

a) Exposure Time [ET]

a.1 Due to the limited extent of the ROW (≈1,500 feet in length) the time required to mow the ROW is only a fraction of the worker's day.

a.2 Hours/day for RME is based on professional judgment using site specific considerations such as the size and location of the of area.

a.3 Hours/day for CTE is assumed to be 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Assumes MDT workers mow the right-of-way once a month during the summer from May through September.

b.2 Assumes hiking occurs in the area 10 days per year for RME during late spring to early fall (May through September) based on the limited spatial extent of the frontage area along the Kootenai River. Exposure frequency also considers days when releases due to soil disturbance activities are unlikely either due to snow cover or high soil moisture content.

b.3 CTE is assumed to be 1/2 RME value.

c) Exposure Duration [ED]

c.1 RME ED is based on professional judgment using site specific considerations.

c.2 Years is recommended mean value for workers in EPA 2011[2].

c.3 Assumes that residents are the most likely recreational users of this area.

The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

<u>**Notes:**</u>

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - environmental protection agency
ET - exposure time
MDT - Montana Department of Transportation
OU - operable unit
RME - reasonable maximum exposure
ROW - right-of-way
TWF - Time Weighted Factor

TABLE 6-14
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU2
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU2	Mowing Hwy 37 ROW	3	0	0	All ND	0.018
	Hiking along Kootenai River	6	0	0	All ND	0.0048

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing Hwy 37 ROW	0	1	5	15	0.00012	**0E+00**	**0**
Recreational Visitor	Hiking along Kootenai River	0	2	10	50	0.0016	**0E+00**	**0**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker	Mowing Hwy 37 ROW	0	1	5	7	0.000057	**0E+00**	**0**
Recreational Visitor	Hiking along Kootenai River	0	1	5	25	0.00020	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-15
Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU3
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Exposure Location	Exposure Scenario	Parameter Type	Exposure Parameters: Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Soil/Duff Disturbance Activities	Recreational Visitor	Forested Area	Hiking	RME	8	[1]	50	[1]	50	[3] c.1	0.033
				CTE	4	[1] a.1	25	[1] b.1	25	[4] c.1	0.0041
			ATV Riding	RME	4	[2]	50	[1]	50	[3] c.1	0.016
				CTE	2	a.1	25	[1] b.1	25	[4] c.1	0.0020
			Camping (campfire building/burning)	RME	2	[2]	50	[1]	50	[3] c.1	0.0082
				CTE	1	[2]	25	[1] b.1	25	[4] c.1	0.0010
		Along Rainy Creek	Hiking	RME	6	[1]	48	[1] b.2	50	[3] c.1	0.023
				CTE	3	[1] a.1	24	[1] b.2	25	[4] c.1	0.0029
		OU3 Roads	Driving	RME	3	[2]	50	[1]	50	[3] c.1	0.012
				CTE	1.5	[2]	25	[1] b.1	25	[4] c.1	0.0015
		Along Kootenai River	Fishing/boating	RME	8	[2]	60	[2]	50	[3] c.1	0.039
				CTE	4	[2] a.1	20	[2]	25	[4] c.1	0.0033
	USFS Firefighter	Forested Area	Cutting firelines	RME	10	[2]	14	[2]	10	[2]	0.0023
				CTE	5	[2] a.1	7	[2] b.1	5	[2] c.1	0.00029
			Wildfire Response	RME	15	[2]	14	[2]	25	[2]	0.0086
				CTE	7.5	a.1	8	[2]	25	[2]	0.0024

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely participants and assumptions reflect this.
[2] Personal communication with United States Forest Service (USFS); email dated 6/24/14.
[3] EPA 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.
[4] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day for CTE is assumed to be 1/2 RME value.
a.2 Days/year firefighting are site-specific based on interviews with USFS[3]. CTE assumes 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Days/year for CTE assumed to be 1/2 RME value.
b.2 Assumes hiking occurs in the area twice per week for RME from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (24 weeks for 2 days per week for RME and 1 day per week for CTE).
b.3 Days/year assumed to be 3 days per week for 24 weeks out of the year (72 days) from Phase V, Part A . SAP/QAPP (EPA 2012).

c) Exposure Duration [ED]

c.1 Assumes that residents are the most likely recreational users of this area.
The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
ATV - all-terrain vehicle
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
SAP/QAPP - sampling and analysis plan/quality assurance project plan
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 6-16
ABS Air Summary Statistics For Disturbances of Soils in OU3
Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Area*	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
					Mean	Maximum	
Recreational Visitor	Hiking	Forest, near	12	1	0.00050	0.0060	0.0042
		Forest, intermed.	37	3	0.00065	0.012	0.0054
		Forest, far	26	1	0.00023	0.0060	0.0052
	ATV Riding	Forest, near	13	2	0.0014	0.012	0.0060
		Forest, intermed.	36	2	0.00050	0.012	0.0060
		Forest, far	27	1	0.00022	0.0060	0.0060
	Campfire building/burning	Forest, near	13	3	0.0023	0.012	0.0060
		Forest, intermed.	37	11	0.0023	0.012	0.0060
		Forest, far	26	2	0.00046	0.0060	0.0060
	Driving	Forest, near	10	1	0.00027	0.0027	0.025
		Forest, intermed.	10	0	0	All ND	0.025
		Forest, far	10	0	0	All ND	0.024
	Hiking	Rainy Creek	10	7	0.0093	0.046	0.0039
	Fishing/boating	Kootenai River	2	0	0	All ND	0.00031
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	10	0	0	All ND	0.0083
		Forest, intermed.	10	8	0.014	0.038	0.0093
		Forest, far	10	6	0.0045	0.013	0.0084
		Forest, NPL boundary	60	7	0.00017	0.0023	0.0010
	Cutting firelines with heavy machinery	Forest, near	10	4	0.0021	0.0077	0.0072
		Forest, intermed.	10	6	0.0029	0.012	0.0088
		Forest, far	10	2	0.0016	0.014	0.011

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine.
Forest, far: greater than or equal to six miles from the mine
Forest, NPL boundary: locations along the NPL boundary evaluated in the nature & extent forest study (see Section 6.6.2.4)

Notes:
ABS - activity-based sampling
ATV - all-terrain vehicle
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
NPL - National Priority List
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 6-17
Estimated Risks from Exposures to LA During Disturbances of Soils in OU3
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Receptor Type	Exposure Scenario	Exposure Area*	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	Hiking	Rainy Creek	0.0093	6	48	50	0.023	**4E-05**	**2**
		Forest, near	0.00050	8	50	50	0.033	**3E-06**	**0.2**
		Forest, intermed.	0.00065	8	50	50	0.033	**4E-06**	**0.2**
		Forest, far	0.00023	8	50	50	0.033	**1E-06**	**0.08**
	ATV-riding	Forest, near	0.0014	4	50	50	0.016	**4E-06**	**0.3**
		Forest, intermed.	0.00050	4	50	50	0.016	**1E-06**	**0.09**
		Forest, far	0.00022	4	50	50	0.016	**6E-07**	**0.04**
	Campfire building/burning	Forest, near	0.0023	2	50	50	0.0082	**3E-06**	**0.2**
		Forest, intermed.	0.0023	2	50	50	0.0082	**3E-06**	**0.2**
		Forest, far	0.00046	2	50	50	0.0082	**6E-07**	**0.04**
	Driving	Forest, near	0.00027	3	50	50	0.012	**6E-07**	**0.04**
		Forest, intermed.	0	3	50	50	0.012	**0E+00**	**0**
		Forest, far	0	3	50	50	0.012	**0E+00**	**0**
	Fishing/boating	Kootenai River	0	8	60	50	0.039	**0E+00**	**0**
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	0	10	14	10	0.0023	**0E+00**	**0**
		Forest, intermed.	0.014	10	14	10	0.0023	**5E-06**	**0.3**
		Forest, far	0.0045	10	14	10	0.0023	**2E-06**	**0.1**
		Forest, NPL boundary	0.00017	10	14	10	0.0023	**7E-08**	**0.004**
	Cutting firelines with heavy machinery	Forest, near	0.0021	10	14	10	0.0023	**8E-07**	**0.05**
		Forest, intermed.	0.0029	10	14	10	0.0023	**1E-06**	**0.07**
		Forest, far	0.0016	10	14	10	0.0023	**6E-07**	**0.04**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Exposure Scenario	Exposure Area*	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	Hiking	Rainy Creek	0.0093	3	24	25	0.0029	**5E-06**	**0.3**
		Forest, near	0.00050	4	25	25	0.0041	**3E-07**	**0.02**
		Forest, intermed.	0.00065	4	25	25	0.0041	**5E-07**	**0.03**
		Forest, far	0.00023	4	25	25	0.0041	**2E-07**	**0.01**
	ATV-riding	Forest, near	0.0014	2	25	25	0.0020	**5E-07**	**0.03**
		Forest, intermed.	0.00050	2	25	25	0.0020	**2E-07**	**0.01**
		Forest, far	0.00022	2	25	25	0.0020	**8E-08**	**0.005**
	Campfire building/burning	Forest, near	0.0023	1	25	25	0.0010	**4E-07**	**0.03**
		Forest, intermed.	0.0023	1	25	25	0.0010	**4E-07**	**0.03**
		Forest, far	0.00046	1	25	25	0.0010	**8E-08**	**0.005**
	Driving	Forest, near	0.00027	1.5	25	25	0.0015	**7E-08**	**0.005**
		Forest, intermed.	0	1.5	25	25	0.0015	**0E+00**	**0**
		Forest, far	0	1.5	25	25	0.0015	**0E+00**	**0**
	Fishing/boating	Kootenai River	0	4	20	25	0.0033	**0E+00**	**0**
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	0	5	7	5	0.00029	**0E+00**	**0**
		Forest, intermed.	0.014	5	7	5	0.00029	**7E-07**	**0.04**
		Forest, far	0.0045	5	7	5	0.00029	**2E-07**	**0.01**
		Forest, NPL boundary	0.00017	5	7	5	0.00029	**8E-09**	**0.0006**
	Cutting firelines with heavy machinery	Forest, near	0.0021	5	7	5	0.00029	**1E-07**	**0.007**
		Forest, intermed.	0.0029	5	7	5	0.00029	**1E-07**	**0.009**
		Forest, far	0.0016	5	7	5	0.00029	**8E-08**	**0.005**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine
Forest, far: greater than or equal to six miles from the mine
Forest, NPL boundary: locations along the NPL boundary evaluated in the nature & extent forest study (see Section 6.6.2.4)

Notes:

ATV - all terrain vehicle
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
NPL - National Priorities List
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-18
Exposure Parameters for Outdoor Air during Soil/Duff Disturbance Activities in OU5
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Time [ET] Value (hours/day)	Exposure Time [ET] Source/ Note	Exposure Frequency [EF] Value (days/year)	Exposure Frequency [EF] Source/ Note	Exposure Duration [ED] Value (years)	Exposure Duration [ED] Source/ Note	Time-weighting Factor [TWF]**
Outdoor Air During Soil/Duff Disturbance Activities	General Outdoor Worker	Industrial properties (outdoor maintenance)	RME	4	[1] a.1	135	[1] b.1	25	[1] c.1	0.022
			CTE	4	[1] a.1	90	[2] b.1	25	[1] c.1	0.015
	Recreational Visitor	Biking on Trails (as adult rider)	RME	2	[4] a.2	48	[4] b.2	50	[3,4] c.2	0.0078
			CTE	1	[4] a.3	24	[4] b.2	25	[4,6] c.2	0.00098
		Biking on Trails (as child in trailer)	RME	2	[4] a.2	48	[4] b.2	5	[4] c.3	0.00078
			CTE	1	[4] a.3	24	[4] b.2	5	[4] c.3	0.00020
		Motocross Participant	RME	4	[5]	40	[5]	55	[5]	0.014
			CTE	2	[5]	30	[5]	35	[5]	0.0034
		Motocross Spectator	RME	4	[5]	60	[5]	45	[5]	0.018
			CTE	4	[5]	30	[5]	45	[5]	0.0088

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.

[2] EPA. 1991. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors". U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[3] EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

[4] Professional judgment using site specific considerations. Recreational scenarios assume that residents are most likely participants and assumptions reflect

[5] Interviews with MotoX Park participants. EPA 2008. *Informed Consent for Personal Air Monitoring at the MotoX Track in Libby, Montana.*
Information on exposure parameters for riders at the MotoX Park was obtained from six volunteers who participated in the MotoX Park ABS investigation (Interviewed on September 10, 2008). See Appendix G-2.

[6] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 The default of 8 hours/day was adjusted by a factor of 0.5 to account for time spent disturbing soil or dust.

a.2 Hours/day biking on trails based on professional judgment.

a.3 Hours/day for CTE is assumed to be 1/2 RME value.

b) Exposure Frequency [EF]

b.1 Default exposure frequency estimates of 219 days/yr (CTE) or 225 days/yr (RME) for outdoor workers were adjusted to account for days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (i.e., November to March) (225 days - 90 days (18 weeks for 5 days per week)=135 days).

b.2 Assumes biking on trails occurs in the area twice per week for RME from late spring to late fall (late April through early October) considering days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (24 weeks for 2 days per week (48 days) for RME and 1 day per week for CTE (24 days).

c) Exposure Duration [ED]

c.1 Years is recommended default for workers in EPA 2002.

c.2 Assumes that residents are the most likely recreational users of this area.

The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

c.3 Default age group (1 to 6 years) for evaluation of exposure to young children.

Notes:

ABS - activity-based sampling
ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 6-19
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU5
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Receptor Type	Exposure Location	Exposure Type	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc-1)
					Mean	Maximum	
Recreational Visitor	MotoX Track	Participant	24	0	0	All ND	0.0098
		Spectator	10	0	0	All ND	0.0011
	Bike Path	Rider	39	3	0.000038	0.00071	0.0010
		Inside Trailer	7	1	0.000053	0.00037	0.0011
Outdoor Worker	Area 1	Worker	6	1	0.00080	0.0048	0.013
	Area 2	Worker	6	2	0.00091	0.0046	0.0040
	Area 3	Worker	6	4	0.0025	0.0091	0.0055
	Area 4	Worker	6	0	0	All ND	0.0043
	Area 5	Worker	6	3	0.0057	0.024	0.024
	Area 6	Worker	6	3	0.0010	0.0029	0.0034
	Area 7	Worker	6	2	0.00071	0.0023	0.0031
	Area 8	Worker	6	4	0.0013	0.0045	0.0028

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor Type	Exposure Location	Exposure Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	MotoX Track	Participant	0	4	40	55	0.014	**0E+00**	**0**
		Spectator	0	4	60	45	0.018	**0E+00**	**0**
	Bike Path	Rider, adult	0.000038	2	48	50	0.0078	**5E-08**	**0.003**
		Trailer, child	0.000053	2	48	5	0.00078	**7E-09**	**0.0005**
Outdoor Worker	Area 1	Worker	0.00080	4	135	25	0.022	**3E-06**	**0.2**
	Area 2	Worker	0.00091	4	135	25	0.022	**3E-06**	**0.2**
	Area 3	Worker	0.0025	4	135	25	0.022	**9E-06**	**0.6**
	Area 4	Worker	0	4	135	25	0.022	**0E+00**	**0**
	Area 5	Worker	0.0057	4	135	25	0.022	**2E-05**	**1**
	Area 6	Worker	0.0010	4	135	25	0.022	**4E-06**	**0.2**
	Area 7	Worker	0.00071	4	135	25	0.022	**3E-06**	**0.2**
	Area 8	Worker	0.0013	4	135	25	0.022	**5E-06**	**0.3**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Exposure Location	Exposure Type	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	MotoX Track	Participant	0	2	30	35	0.0034	**0E+00**	**0**
		Spectator	0	4	30	45	0.0088	**0E+00**	**0**
	Bike Path	Rider, adult	0.000038	1	24	25	0.00098	**6E-09**	**0.0004**
		Trailer, child	0.000053	1	24	5	0.00020	**2E-09**	**0.0001**
Outdoor Worker	Area 1	Worker	0.00080	4	90	25	0.015	**2E-06**	**0.1**
	Area 2	Worker	0.00091	4	90	25	0.015	**2E-06**	**0.1**
	Area 3	Worker	0.0025	4	90	25	0.015	**6E-06**	**0.4**
	Area 4	Worker	0	4	90	25	0.015	**0E+00**	**0**
	Area 5	Worker	0.0057	4	90	25	0.015	**1E-05**	**0.9**
	Area 6	Worker	0.0010	4	90	25	0.015	**3E-06**	**0.2**
	Area 7	Worker	0.00071	4	90	25	0.015	**2E-06**	**0.1**
	Area 8	Worker	0.0013	4	90	25	0.015	**3E-06**	**0.2**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
OU - operable unit
PCME - phase contrast microscopy - equivalent
LA - Libby amphibole asbestos
ND - non-detect
N - number
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-20
Exposure Parameters During Soil/Duff Disturbance Activities in OU6
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance	BNSF Workers	Railroad Maintenance	RME	8	[1] a.1	60	[3]	50	[3]	0.039
			CTE	8	[1] a.1	10	[2,3]	30	[5] b.1	0.0039
	Trespasser	On-looker	RME	2	[3]	60	[3,4]	15	[2,3]	0.0029
			CTE	2	[3]	10	[3,4]	9	[2,3]	0.00029
		Pedestrian trespasser	RME	4	[3]	60	[3,4]	50	[5] b.2	0.020
			CTE	4	[3]	10	[3,4]	25	[6] b.2	0.0016

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.
[2] Professional judgment using site specific considerations.
[3] Information provided by Burlington Northern (BN). BN 2013. Risk Calculations for Human Health Risk Assessment, Memorandum. Prepared by TRC for the U.S. Environmental Protection Agency. January 2014.
[4] As provided in the ABS SAP (ENSR/AECOM, 2008).
[5] EPA. 1991. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors". U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.
[6] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day is the recommended default for workers in EPA 2002[1]; the default for indoor workers and outdoor workers is 8 hours/day.

b) Exposure Duration [ED]

b.1 Assumed based on USEPA standard default exposure factors (USEPA, 1991).
b.2 Assumes that residents are the most likely exposed receptors.
The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

Notes:

ABS - activity-based sampling
ATSDR - Agency for Toxic Substances and Disease Registry
BN - Burlington Northern
BNSF - Burlington Northern Santa Fe
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
SAP - sampling and analysis plan
TWF - time-weighting factor

TABLE 6-21
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU6
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU6	Pedestrian tresspasser	14	0	0	All ND	0.00065
	On-looker	7	0	0	All ND	0.0010
	BNSF worker	14	0	0	All ND	0.00034

Panel B: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU6	Pedestrian tresspasser	0	4	60	50	0.020	**0E+00**	**0**
	On-looker	0	2	60	15	0.0029	**0E+00**	**0**
	BNSF worker	0	8	60	50	0.039	**0E+00**	**0**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Operable Unit	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU6	Pedestrian tresspasser	0	4	10	25	0.0016	**0E+00**	**0**
	On-looker	0	2	10	9	0.00029	**0E+00**	**0**
	BNSF worker	0	8	10	30	0.0039	**0E+00**	**0**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
BNSF - Burlington Northern Santa Fe
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-22
Exposure Parameters for Outdoor Air During Soil/Duff Disturbance Activities in OU8
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Soil/Duff Disturbance Activities	Residents	Driving on Libby roads	RME	2	[4] a.2	225	[4] b.1	50	[1] c.1	0.037
			CTE	1	[4] a.2	113	[4] b.1	25	[6] c.1	0.0046
		Driving on Troy roads	RME	0.75	[5]	225	[4] b.1	50	[1] c.1	0.014
			CTE	0.5	[5]	113	[4] b.1	25	[6] c.1	0.0023
	Recreational Visitors	Hiking, biking, ATV riding along ROW	RME	4	[4] a.3	184	[4] b.2	30	[4] c.2	0.036
			CTE	2	[4] a.3	90	[4] b.2	15	[4] c.2	0.0044
	Outdoor Worker (MDT Maintenance Worker)	Rotomilling, brush-clearing along ROW	RME	8	[2] a.1	60	[2] b.3	30	[4] c.3	0.023
			CTE	8	[2] a.1	12	[3] b.4	30	[4] c.3	0.0047

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA. 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

[2] EPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.

[3] EPA. 1991. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors". U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[4] Professional judgment using site specific considerations.

[5] Adjusted based on Troy vs Libby city size.

[6] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day is the recommended default for workers in EPA 2002[2]; the default for outdoor workers is 8 hours/day.

a.2 Hours/day spent driving on Troy roads are based on professional judgment[4] using site specific considerations.

a.3 Hours/day spent hiking, biking, or ATV riding driving on roads in OU8 are based on professional judgment[4] using site specific considerations.

b) Exposure Frequency [EF]

b.1 Days/year are site specific [4]. Default exposure frequency estimate of 350 days/year was adjusted to account for days when releases due to soil were unlikely either due to snow cover or high soil moisture content (i.e., November to March) (350 days - 126 days (18 weeks for 7 days per week)=224 days, rounded to 225) disturbance activities. CTE is 1/2 the RME value or 113 days.

b.2 184 days/year assumes daily exposure from April through September, during the warmer months of the year. 90 days/year assumes daily exposure for three summer months.

b.3 60 days/year assumes three months of exposure working 5-day work weeks, 4 weeks per month, with weekends off.

b.4 An EF of 12 days per year considers approximately 240 miles of roadway spanning both sides of all OU8 state highways (~120 miles for one side of the highway) and assumes three days of brush hogging or rotomilling, to occur twice a year, and accounts for variability in brush hogging or rotomilling efficiency. Example (240 miles @ average mowing speed of 10 mph): 3 days mowing @ 8 hrs/day x 2 mowing operations/yr = 6 mowing days/yr. This estimate is doubled to account for 50% efficiency in operator differences, resulting in an effective exposure frequency of 12 days/year.

c) Exposure Duration [ED]

c.1 Assumes that residents are the most likely exposed receptors.
The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

c.2 Years for workers is site specific considering workers are also residents.

c.3 Years is recommended mean value for workers in EPA 2011[1].

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
ATV - all-terrain vehicle
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
MDT - Montana Department of Transportation
OU - operable unit
RME - reasonable maximum exposure
ROW - right-of-way
TWF - time-weighting factor

TABLE 6-23
ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU8
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

Operable Unit	Exposure Scenario	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU8	ATV riding ROW	16	1	0.00018	0.0028	0.0029
	Brush-clearing ROW	14	6	0.0036	0.018	0.0036
	Rotomilling	61	1	0.000049	0.0030	0.0036
	Driving on Libby roads	20	0	0	All ND	0.00065
	Driving on Troy roads	20	7	0.00033	0.0028	0.00022

Panel B: Risk Estimates Based on RME Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-Cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational	ATV riding ROW	0.00018	4	184	30	0.036	**1E-06**	**0.07**
Outdoor Worker	Brush-clearing ROW	0.0036	8	60	30	0.023	**1E-05**	**0.9**
	Rotomilling	0.000049	8	60	30	0.023	**2E-07**	**0.01**
Various	Driving on Libby roads	0	2	225	50	0.037	**0E+00**	**0**
	Driving on Troy roads	0.00033	0.75	225	50	0.014	**8E-07**	**0.05**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Receptor	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-Cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational	ATV riding ROW	0.00018	2	90	15	0.0044	**1E-07**	**0.009**
Outdoor Worker	Brush-clearing ROW	0.0036	8	12	30	0.0047	**3E-06**	**0.2**
	Rotomilling	0.000049	8	12	30	0.0047	**4E-08**	**0.003**
Various	Driving on Libby roads	0	1	113	25	0.0046	**0E+00**	**0**
	Driving on Troy roads	0.00033	0.5	113	25	0.0023	**1E-07**	**0.008**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

Notes:

ABS - activity-based sampling
ATV - all-terrain vehicle
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
ROW - right-of-way
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 6-24
Estimated Risks from Exposure to LA During Background Soil Disturbances
Libby Asbestos Superfund Site

Panel A: Summary Statistics for ABS Air

ABS Script	ABS Dataset*	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
"Bucket of dirt" digging	OU4 Background Areas	33	7	0.0016	0.019	0.00072
	OU7 Background Areas	11	7	0.00032	0.0011	0.00048
	OU4 Topsoil Borrow Sources	15	4	0.000046	0.00020	0.00011
Raking, mowing, digging	OU4 "Curb-to-Curb" Yards	31	8	0.00039	0.0049	0.00025

Panel B: Risk Estimates Based on RME Exposure Parameters

ABS Script	ABS Dataset*	EPC	RME Exposure Parameters++				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
"Bucket of dirt" digging	OU4 Background Areas	0.0016	6.6	60	50	0.032	**9E-06**	**0.6**
	OU7 Background Areas	0.00032	6.6	60	50	0.032	**2E-06**	**0.1**
	OU4 Topsoil Borrow Sources	0.000046	6.6	60	50	0.032	**3E-07**	**0.02**
Raking, mowing, digging	OU4 "Curb-to-Curb" Yards	0.00039	6.6	60	50	0.032	**2E-06**	**0.1**

* See the *Background Soil Summary Report* (CDM Smith 2014j) for a detailed discussion of each type of ABS dataset.
+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4).
++ Exposure parameters for the RME residential yard soil disturbance scenario are used in the risk estimates.

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-1
Exposure Parameters for Indoor Air Inside Residential/Commercial Properties in OU4 and OU7
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Ambient Conditions During Indoor Dust Disturbance	Resident	Passive Behaviors (e.g., sleeping, watching TV)	RME	16.9	[1] a.1	350	[4] b.1	50	[1] c.1	0.48
			CTE	14.9	[1] a.1	350	[4] b.1	25	[6] c.1	0.21
		Active Behaviors (e.g., house cleaning)	RME	5.8	[1] a.2	350	[4] b.1	50	[1] c.1	0.17
			CTE	1.5	[1] a.2	350	[4] b.1	25	[6] c.1	0.021
	Indoor Workers	Passive Behaviors (e.g., sitting at a desk)	RME	4	[2] a.3	250	[2] b.2	25	[2] c.2	0.041
			CTE	4	[2] a.3	219	[4] b.2	7	[1] c.3	0.010
		Active Behaviors (e.g., cleaning, walking)	RME	4	[2] a.3	250	[2] b.2	25	[2] c.2	0.041
			CTE	4	[2] a.3	219	[4] b.2	7	[1] c.3	0.010
Indoor Air During VI Disturbance Activities	Tradesperson	Worker	RME	4	[5] a.4	250	[2] b.2	25	[2] c.2	0.041
			CTE	4	[5] a.4	219	[4] b.2	7	[1] c.3	0.010

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.

[2] EPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.

[3] EPA 1997: Exposure Factors Handbook. Vol. 1: General Factors. ORD. EPA/600/P-95/002Fa.

[4] EPA 1991. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors". U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

[5] Professional judgment using site specific considerations.

[6] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 Hours/day spent passively are calculated based on recommended default assumptions in EPA 2011 [1]; ET is assumed to be equal to the total indoor ET minus the active ET. Hours/day at residence (total) = 16.4 (CTE) to 22.7 (RME) (EPA 2011,Table 16-1).

a.2 Hours/day spent house cleaning (active) are EPA recommended default values in EPA 2011[1], Table 16-26. RME is 95th percentile, CTE is mean value.

a.3 Hours/day is the recommended default for workers in EPA 2002[2]; the default for indoor workers and outdoor workers is 8 hours/day. This was assumed to be spent on active and passive behaviors equally (4 hours each).

a.4 The default of 8 hours/day was adjusted by a factor of 0.5 to account for time spent disturbing soil or dust.

b) Exposure Frequency [EF]

b.1 Days/year at residence. Recommended default for residents in EPA 1991[4] (350 days/year is based on the assumption the resident spends a 2 week vacation each year away from residence).

b.2 Days/year is recommended default for workers in EPA 2002[2]; RME default for indoor workers is 250 days/year, CTE is 219 days/yr.

c) Exposure Duration [ED]

c.1 The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

c.2 Years is recommended default for workers in EPA 2002[2].

c.3 Years is recommended mean value for workers in EPA 2011[1].

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor

TABLE 7-2
Exposure Point Concentrations For Indoor ABS Air During Residential/Commercial Disturbances
Libby Asbestos Superfund Site

Interior Removal Classification	Behavior Type	N Samples	Mean Seasonal PCME LA Air Conc. (s/cc)[a]				
			Spring	Summer	Fall	Winter	EPC (Average Mean Across Seasons)
OU4: Residential Properties in Libby							
Pre-removal	Active	42	0.0035	0.000016	0.00036	0.00011	0.00099
	Passive	29	0.00011	0.000099	--	0	0.000068
Post-removal	Active	131	0.00010	0.00022	0.00032	0.000093	0.00018
	Passive	132	0.000032	0.000041	0.000045	0.0000081	0.000032
No removal	Active	202	0.000071	0.00016	0.000064	0.000084	0.000095
	Passive	217	0.000025	0.000077	0.000027	0.000025	0.000038
OU4: Commercial Properties in Libby							
Pre-removal	Active	6	0.0092	0.00073	--	0	0.0033
	Passive	5	0.000021	0.00080	--	0	0.00027
Post-removal	Active	6	0.00027	0.00012	--	0	0.00013
	Passive	6	0.000029	0	--	0	0.0000096
No removal	Active	6	0	0.00062	--	0	0.00021
	Passive	7	0	0.000077	--	0.000039	0.000039
OU7: Residential Properties in Troy[b]							
Post-removal	Active	22	0.000029	--	0.000024	--	0.000027
	Passive	22	0.000014	--	0.000012	--	0.000013
No removal	Active	14	0.000012	--	0.00010	--	0.000056
	Passive	14	0.0000055	--	0.000026	--	0.000016
OU7: Commercial Properties in Troy[b]							
No removal	Active	4	0.000069	--	0.000023	--	0.000046
	Passive	4	0.0000096	--	0	--	0.0000048

-- = no samples collected in this season.

[a] Seasons are defined as follows: Spring (March, April, May), Summer (June, July, August), Fall (September, October, November), and Winter (December, January, February).

[b] No pre-removal data is available for Troy. Samples collected in late February have been grouped into "spring".

Notes:

ABS - activity-based sampling
Conc. - concentration
EPC - exposure point concentration
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase-contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 7-3
Estimated Residential and Indoor Worker Risks from Exposure to LA from Indoor Air in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Operable Unit	Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Resident	Residential Properties - "Pre-Removal"	Active Behaviors	0.00099	5.8	350	50	0.17	**3E-05**	**2**
			Passive Behaviors	0.000068	16.9	350	50	0.48	**6E-06**	**0.4**
								Total:	**3E-05**	**2**
		Residential Properties - "Post-Removal"	Active Behaviors	0.00018	5.8	350	50	0.17	**5E-06**	**0.3**
			Passive Behaviors	0.000032	16.9	350	50	0.48	**3E-06**	**0.2**
								Total:	**8E-06**	**0.5**
		Residential Properties - "No Removal"	Active Behaviors	0.000095	5.8	350	50	0.17	**3E-06**	**0.2**
			Passive Behaviors	0.000038	16.9	350	50	0.48	**3E-06**	**0.2**
								Total:	**6E-06**	**0.4**
	Indoor Worker	Commercial Properties - "Pre-Removal"	Active Behaviors	0.0033	4	250	25	0.041	**2E-05**	**2**
			Passive Behaviors	0.00027	4	250	25	0.041	**2E-06**	**0.1**
								Total:	**2E-05**	**2**
		Commercial Properties - "Post-Removal"	Active Behaviors	0.00013	4	250	25	0.041	**9E-07**	**0.06**
			Passive Behaviors	0.0000096	4	250	25	0.041	**7E-08**	**0.004**
								Total:	**1E-06**	**0.06**
		Commercial Properties - "No Removal"	Active Behaviors	0.00021	4	250	25	0.041	**1E-06**	**0.09**
			Passive Behaviors	0.000039	4	250	25	0.041	**3E-07**	**0.02**
								Total:	**2E-06**	**0.1**
OU7	Resident	Residential Properties - "Post-Removal"	Active Behaviors	0.000027	5.8	350	50	0.17	**8E-07**	**0.05**
			Passive Behaviors	0.000013	16.9	350	50	0.48	**1E-06**	**0.07**
								Total:	**2E-06**	**0.1**
		Residential Properties - "No Removal"	Active Behaviors	0.000056	5.8	350	50	0.17	**2E-06**	**0.1**
			Passive Behaviors	0.000016	16.9	350	50	0.48	**1E-06**	**0.08**
								Total:	**3E-06**	**0.2**
	Indoor Worker	Commercial Properties - "No Removal"	Active Behaviors	0.000046	4	250	25	0.041	**3E-07**	**0.02**
			Passive Behaviors	0.0000048	4	250	25	0.041	**3E-08**	**0.002**
									4E-07	**0.02**

TABLE 7-3
Estimated Residential and Indoor Worker Risks from Exposure to LA from Indoor Air in OU4 and OU7
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4	Resident	Residential Properties - "Pre-Removal"	Active Behaviors	0.00099	1.5	350	25	0.021	**4E-06**	**0.2**
			Passive Behaviors	0.000068	14.9	350	25	0.21	**2E-06**	**0.2**
								Total:	**6E-06**	**0.4**
		Residential Properties - "Post-Removal"	Active Behaviors	0.00018	1.5	350	25	0.021	**7E-07**	**0.04**
			Passive Behaviors	0.000032	14.9	350	25	0.21	**1E-06**	**0.07**
								Total:	**2E-06**	**0.1**
		Residential Properties - "No Removal"	Active Behaviors	0.000095	1.5	350	25	0.021	**3E-07**	**0.02**
			Passive Behaviors	0.000038	14.9	350	25	0.21	**1E-06**	**0.09**
								Total:	**2E-06**	**0.1**
	Indoor Worker	Commercial Properties - "Pre-Removal"	Active Behaviors	0.0033	4	219	7	0.010	**6E-06**	**0.4**
			Passive Behaviors	0.00027	4	219	7	0.010	**5E-07**	**0.03**
								Total:	**6E-06**	**0.4**
		Commercial Properties - "Post-Removal"	Active Behaviors	0.00013	4	219	7	0.010	**2E-07**	**0.01**
			Passive Behaviors	0.0000096	4	219	7	0.010	**2E-08**	**0.001**
								Total:	**2E-07**	**0.01**
		Commercial Properties - "No Removal"	Active Behaviors	0.00021	4	219	7	0.010	**4E-07**	**0.02**
			Passive Behaviors	0.000039	4	219	7	0.010	**7E-08**	**0.004**
								Total:	**4E-07**	**0.02**
OU7	Resident	Residential Properties - "Post-Removal"	Active Behaviors	0.000027	1.5	350	25	0.021	**1E-07**	**0.006**
			Passive Behaviors	0.000013	14.9	350	25	0.21	**5E-07**	**0.03**
								Total:	**6E-07**	**0.04**
		Residential Properties - "No Removal"	Active Behaviors	0.000056	1.5	350	25	0.021	**2E-07**	**0.01**
			Passive Behaviors	0.000016	14.9	350	25	0.21	**6E-07**	**0.04**
								Total:	**8E-07**	**0.05**
	Indoor Worker	Commercial Properties - "No Removal"	Active Behaviors	0.000046	4	219	7	0.010	**8E-08**	**0.005**
			Passive Behaviors	0.0000048	4	219	7	0.010	**8E-09**	**0.0005**
									9E-08	**0.006**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-4
Summary Statistics During Indoor Tradesperson Activities
Libby Asbestos Superfund Site

Activity Description	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)		Mean Achieved Sensitivity (cc^{-1})
			Mean[a]	Maximum	
Bulk removal	4	4 [b]	0.044	0.12	0.0017
Demolition	4	4	0.0078	0.028	0.0012
Detailing attic	5	5	0.025	0.12	0.0010
Wet wipe/HEPA vacuum in living space	4	4 [c]	0.015	0.030	0.0027

[a] The mean PCME concentration was selected as the EPC.
[b] One sample also reported detected structures of chrysotile and amosite.
[c] All samples also reported detected structures of chrysotile and/or amosite, crocidolite, and anthophyllite.

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
EPC - exposure point concentraion
HEPA - high-efficiency particulate air
LA - Libby amphibole asbestos
N - number
PCME - phase-contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 7-5
Estimated Tradesperson Risks from Exposure to LA from Indoor Air in OU4 and OU7
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Tradesperson, worker	OU4/OU7, Residential/ Commerical Properties	Bulk VI Removal	0.044	4	250	25	0.041	**3E-04**	**20**
		Demolition	0.0078	4	250	25	0.041	**5E-05**	**4**
		Detailing attic	0.025	4	250	25	0.041	**2E-04**	**10**
		Wet wipe/HEPA vac	0.015	4	250	25	0.041	**1E-04**	**7**

Panel B: Risk Estimates Based on CTE Exposure Parameters

Receptor Type	Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Tradesperson, worker	OU4/OU7, Residential/ Commerical Properties	Bulk VI Removal	0.044	4	219	7	0.010	**7E-05**	**5**
		Demolition	0.0078	4	219	7	0.010	**1E-05**	**0.9**
		Detailing attic	0.025	4	219	7	0.010	**4E-05**	**3**
		Wet wipe/HEPA vac	0.015	4	219	7	0.010	**3E-05**	**2**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4).

Notes:

Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HEPA - high-efficiency particulate air
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-6
Exposure Parameters for Indoor Air During Typical School Activities in OU4
Libby Asbestos Superfund Site

Exposure Media & Disturbance Description	Receptor Group	Building Description	Exposure Parameters [1]			
			Exposure Time [ET] (hours/day)	Exposure Frequency [EF] (days/year)	Exposure Duration [ED] (years)	Time-weighting Factor [TWF]**
Indoor Air During Typical School Activities	Student	Kootenai Valley Head Start	7	200	2	0.0046
		Libby Elementary School	7	200	6	0.014
		Libby High School	7	200	4	0.0091
		Libby Middle School	7	200	3	0.0068
		Libby Admin. Building[a]	7	200	6	0.014
	Teacher	All Schools	8	210	25	0.068

** TWF calculated as ET/24 · EF/365 · ED/70

[a] Classes are held in the Libby Administration Building

Source Citations:

[1] All OU4 exposure parameters are based on interviews with school administrators at each school (EPA 2010). Both the indoor and outdoor exposure assumptions were developed to be representative of the entire year, which includes extreme variations in weather. There is no separation of active and passive indoor activities. EPA. 2010. Public Schools Asbestos Sampling Summary Report. Libby, Montana, Superfund Site. July.

Notes:

ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
TWF - time-weighting factor

TABLE 7-7
Summary Statistics During Indoor Activities at Schools in OU4
Libby Asbestos Superfund Site

School Building	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
			Mean	Maximum	
Kootenai Valley Head Start	10	0	0	All ND	0.00057
Libby Elementary School	10	1	0.000059	0.00059	0.00056
Libby Middle School	10	1	0.000051	0.00051	0.00056
Libby High School	10	0	0	All ND	0.00054
Libby Public Schools Admin. Building	10	0	0	All ND	0.00058

+Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter

TABLE 7-8
Estimated Risks from Exposure to LA from Indoor Air in OU4 Schools
Libby Asbestos Superfund Site

Receptor Type	Building Description	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Student	Kootenai Valley Head Start	0	7	200	2	0.0046	**0E+00**	**0**
	Libby Elementary School	0.000059	7	200	6	0.014	**1E-07**	**0.009**
	Libby Middle School	0.000051	7	200	3	0.0068	**6E-08**	**0.004**
	Libby High School	0	7	200	4	0.0091	**0E+00**	**0**
	Libby Admin. Building	0	7	200	6	0.014	**0E+00**	**0**
Teacher	Kootenai Valley Head Start	0	8	210	25	0.068	**0E+00**	**0**
	Libby Elementary School	0.000059	8	210	25	0.068	**7E-07**	**0.05**
	Libby Middle School	0.000051	8	210	25	0.068	**6E-07**	**0.04**
	Libby High School	0	8	210	25	0.068	**0E+00**	**0**
	Libby Admin. Building	0	8	210	25	0.068	**0E+00**	**0**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-9
Exposure Parameters for the Search and Rescue Building in OU1
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						Time-weighting Factor [TWF]**
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Indoor Air	Search and Rescue Volunteer	Indoor Activities	RME	3.2	[2]	147	[2]	50	[1]	0.038
			CTE	1.7	[2]	72	[2]	25	[1]	0.0050

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] Professional judgment using site specific considerations; assumes volunteers are Libby residents.

[2] Questionnaires for search and rescue volunteers (see Appendix G.1). RME is equal to the 95th percentile; CTE is equal to the mean across all respondents.

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OU - operable unit
RME - reasonable maximum exposure
SRC - Syracuse Research Company
TWF - time-weighting factor

TABLE 7-10
Air Summary Statistics and Estimated Risks from Exposure to LA in Indoor Air at the Search and Rescue Building in OU1
Libby Asbestos Superfund Site

Panel A: Summary Statistics for Clearance Air Samples

Operable Unit	Exposure Location	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Sensitivity (cc^{-1})
				Mean	Maximum	
OU1	Office	2	2	0.00033	0.00038	0.00024
	Garage	3	3	0.00022	0.00028	0.00024

Panel B: Risk Estimates Based on RME Exposure Parameters

Exposure Location	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Office	Active (high-end)	0.00033	3.2	147	50	0.038	**2E-06**	**0.1**
Garage	Active (high-end)	0.00022	3.2	147	50	0.038	**1E-06**	**0.09**

Panel C: Risk Estimates Based on CTE Exposure Parameters

Exposure Location	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Office	Active (high-end)	0.00033	1.7	72	25	0.0050	**3E-07**	**0.02**
Garage	Active (high-end)	0.00022	1.7	72	25	0.0050	**2E-07**	**0.01**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:
cc^{-1} - per cubic centimeter
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
N - number
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 7-11
Exposure Parameters for Indoor Air in Buildings in OU5
Libby Asbestos Superfund Site

Building Description	Parameter Type	Exposure Scenario	Exposure Parameters [1]			
			Exposure Time [ET]	Exposure Frequency [EF]	Exposure Duration [ED]	Time-weighting Factor (TWF)
			Value (hours/ day)	Value (days/ year)	Value (years)	
Occupied Buildings						
B+C Packaging	RME	Active Behaviors	1	300	5	0.0024
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	6.2	180	2	0.0036
		Passive Behaviors	*100% of time assumed to be active for CTE*			
Bioreactor Building	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	4	219	10	0.014
		Passive Behaviors	4	219	10	0.014
CDM Smith Main Office	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	0.4	250	10	0.0016
		Passive Behaviors	7.6	250	10	0.031
Central Maintenance Building	RME	Active Behaviors	8	319	27	0.11
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	2.55	146	11	0.0067
		Passive Behaviors	0.45	146	11	0.0012
Fire Hall	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	4	219	10	0.014
		Passive Behaviors	4	219	10	0.014
Log Yard Truck Scale House	RME	Active Behaviors	0.083	10	25	0.000034
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	0.07	9	13	0.000013
		Passive Behaviors	*100% of time assumed to be active for CTE*			
Luck EG Electric Motor Shed	RME	Active Behaviors	0.33	300	15	0.0024
		Passive Behaviors	*100% of time assumed to be active for RME*			
	CTE	Active Behaviors	0.22	*280*	*8*	0.00080
		Passive Behaviors	*100% of time assumed to be active for CTE*			
Office/Laboratory	RME	Active Behaviors	6.4	250	25	0.065
		Passive Behaviors	1.6	250	25	0.016
	CTE	Active Behaviors	4	219	10	0.014
		Passive Behaviors	4	219	10	0.014
Vacant Buildings						
All buildings	RME	Active (high-end)	8	250	25	0.082
	CTE	Active (high-end)	8	219	10	0.029

** TWF calculated as ET/24 · EF/365 · ED/70

[1] All occupied building exposure parameters are based on building-specific surveys. See Appendix G-3 for survey results. Vacant building exposure parameters are based on default worker parameters (EPA 1991, 2002).

Source Citations:

EPA 1991. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. Supplemental Guidance: "Standard Default Exposure Factors". U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER Directive 9285.6-03. Interim Final. March 25, 1991.

EPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.

Notes:

CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
% - percent

TABLE 7-12
Summary Statistics for Indoor ABS at Buildings in OU5
Libby Asbestos Superfund Site

Building	ABS Type	N Samples	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)*		Mean Achieved Sensitivity (cc^{-1})
				Mean	Maximum	
Occupied Buildings						
B+C Packaging	Active	4	1	0.000094	0.00038	0.0060
B+C Packaging	Passive	1	0	0	All ND	0.00049
Bioreactor Building	Active	2	1	0.00023	0.00047	0.00061
Bioreactor Building	Passive	1	0	0	All ND	0.00049
CDM Smith Main Office	Active	5	3	0.0013	0.0049	0.0039
CDM Smith Main Office	Passive	2	0	0	All ND	0.00049
Central Maintenance Building	Active	4	1	0.0010	0.0041	0.014
Central Maintenance Building	Passive	1	1	0.00021	0.00021	0.00053
Fire Hall	Active	2	0	0	All ND	0.0059
Fire Hall	Passive	1	0	0	All ND	0.00049
Log Yard Truck Scale House	Active	6	3	0.0065	0.016	0.060
Log Yard Truck Scale House	Passive	1	0	0	All ND	0.00050
Luck EG Electric Motor Shed	Active	3	3	0.0025	0.0042	0.0024
Luck EG Electric Motor Shed	Passive	1	0	0	All ND	0.00045
Office/Laboratory	Active	2	1	0.00025	0.00049	0.00084
Office/Laboratory	Passive	1	0	0	All ND	0.00049
Vacant Buildings						
Chemical Storage Building	Active*	5	0	0	All ND	0.00049
Diesel Fire Pump House	Active*	5	2	0.00011	0.00037	0.00083
Electric Pump House	Active*	5	2	0.00034	0.00085	0.0021
Intermediate Injection Building	Active*	5	0	0	All ND	0.00048
LTU Leachate Building #1	Active*	5	1	0.000039	0.00019	0.00049
LTU Leachate Building #2	Active*	5	0	0	All ND	0.00049
Pipe Shop	Active*	5	0	0	All ND	0.0022
Power house/office	Active*	5	0	0	All ND	0.00091
Shed 12	Active*	5	0	0	All ND	0.00039
Tank Farm Building	Active*	5	0	0	All ND	0.00049

[+] Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

* Samples collected following active disturbances with a leaf-blower.

Notes:

ABS - activity-based sampling

cc^{-1} - per cubic centimeter

Conc. - concentration

OU - operable unit

LA - Libby amphibole asbestos

N - number

ND - non-detect

PCME - phase contrast microscopy - equivalent

s/cc - structures per cubic centimeter

TABLE 7-13
Estimated Risks from Exposure to LA from Indoor Air in OU5
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Occupied Buildings								
B+C Packaging	Active Behaviors	0.000094	1	300	5	0.0024	**4E-08**	**0.003**
	Passive Behaviors	0	*100% of time assumed to be active for RME*					
Bioreactor Building	Active Behaviors	0.00023	6.4	250	25	0.065	**3E-06**	**0.2**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
CDM Smith Libby Field Office	Active Behaviors	0.0013	6.4	250	25	0.065	**1E-05**	**1**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
Central Maintenance Building	Active Behaviors	0.0010	8	319	27	0.11	**2E-05**	**1**
	Passive Behaviors	0.00021	*100% of time assumed to be active for RME*					
Fire Hall	Active Behaviors	0	6.4	250	25	0.065	**0E+00**	**0**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
Log Yard Truck Scale House	Active Behaviors	0.0065	0.083	10	25	0.000034	**4E-08**	**0.002**
	Passive Behaviors	0	*100% of time assumed to be active for RME*					
Luck EG Electric Motor Shed	Active Behaviors	0.0025	0.33	300	15	0.0024	**1E-06**	**0.07**
	Passive Behaviors	0	*100% of time assumed to be active for RME*					
Office/Laboratory	Active Behaviors	0.00025	6.4	250	25	0.065	**3E-06**	**0.2**
	Passive Behaviors	0	1.6	250	25	0.016	**0E+00**	**0**
Vacant Buildings								
Chemical Storage Building	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Diesel Fire Pump House	Active (high-end)	0.00011	8	250	25	0.082	**2E-06**	**0.1**
Electric Pump House	Active (high-end)	0.00034	8	250	25	0.082	**5E-06**	**0.3**
Intermediate Injection Building	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
LTU Leachate Building #1	Active (high-end)	0.000039	8	250	25	0.082	**5E-07**	**0.04**
LTU Leachate Building #2	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Pipe Shop	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Power house/office	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Shed 12	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**
Tank Farm Building	Active (high-end)	0	8	250	25	0.082	**0E+00**	**0**

TABLE 7-13
Estimated Risks from Exposure to LA from Indoor Air in OU5
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Building Description	Exposure Scenario	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
		Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Occupied Buildings								
B+C Packaging	Active Behaviors	0.000094	6.2	180	2	0.0036	**6E-08**	**0.004**
	Passive Behaviors	0	*100% of time assumed to be active for CTE*					
Bioreactor Building	Active Behaviors	0.00023	4	219	10	0.014	**6E-07**	**0.04**
	Passive Behaviors	0	4	219	10	0.014	**0E+00**	**0**
CDM Smith Libby Field Office	Active Behaviors	0.0013	0.4	250	10	0.0016	**4E-07**	**0.02**
	Passive Behaviors	0	7.6	250	10	0.031	**0E+00**	**0**
Central Maintenance Building	Active Behaviors	0.0010	2.55	146	11	0.0067	**1E-06**	**0.08**
	Passive Behaviors	0.00021	0.45	146	11	0.0012	**4E-08**	**0.003**
Fire Hall	Active Behaviors	0	4	219	10	0.014	**0E+00**	**0**
	Passive Behaviors	0	4	219	10	0.014	**0E+00**	**0**
Log Yard Truck Scale House	Active Behaviors	0.0065	0.07	9	13	0.000013	**1E-08**	**0.001**
	Passive Behaviors	0	*100% of time assumed to be active for CTE*					
Luck EG Electric Motor Shed	Active Behaviors	0.0025	0.22	*280*	*8*	0.00080	**3E-07**	**0.02**
	Passive Behaviors	0	*100% of time assumed to be active for CTE*					
Office/Laboratory	Active Behaviors	0.00025	4	219	10	0.014	**6E-07**	**0.04**
	Passive Behaviors	0	4	219	10	0.014	**0E+00**	**0**
Vacant Buildings								
Chemical Storage Building	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Diesel Fire Pump House	Active (high-end)	0.00011	8	219	10	0.029	**5E-07**	**0.04**
Electric Pump House	Active (high-end)	0.00034	8	219	10	0.029	**2E-06**	**0.1**
Intermediate Injection Building	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
LTU Leachate Building #1	Active (high-end)	0.000039	8	219	10	0.029	**2E-07**	**0.01**
LTU Leachate Building #2	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Pipe Shop	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Power house/office	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Shed 12	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**
Tank Farm Building	Active (high-end)	0	8	219	10	0.029	**0E+00**	**0**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

Notes:

Conc. - concentration	LA - Libby amphibole asbestos
CTE - central tendency exposure	OU - operable unit
ED - exposure duration	PCME - phase contrast microscopy - equivalent
EF - exposure frequency	RME - reasonable maximum exposure
EPC - exposure point concentration	s/cc - structures per cubic centimeter
ET - exposure time	TWF - time-weighting factor
HQ - hazard quotient	% - percent

TABLE 8-1
Exposure Parameters For Outdoor Air During Wood-Related Activities
Libby Asbestos Superfund Site

Exposure Media	Receptor Type	Scenario	Parameter Type	Exposure Parameters						
				Exposure Time [ET]		Exposure Frequency [EF]		Exposure Duration [ED]		Time-weighting Factor [TWF]**
				Value (hours/day)	Source/ Note	Value (days/year)	Source/ Note	Value (years)	Source/ Note	
Outdoor Air During Tree Bark Disturbance Activities	Resident	Local Wood Harvesting (e.g., cutting and hauling)	RME	10	[3]	15	[3]	40	[5] c.5	0.0098
			CTE	5	a.2	5	[3]	20	[5] c.5	0.00082
	Outdoor Worker	Commercial Logger - Hand-felling	RME	8	[3]	24	[3]	6	[6]	0.0019
			CTE	8	[3]	8	[3]	6	[6]	0.00063
		Commercial Logger - skidding/mechanical processing/site restoration	RME	10	[3]	24	[3]	12	[6]	0.0047
			CTE	8	[3]	8	[3]	12	[6]	0.0013
		Landfill workers- wood-chipping & OU5 worker-pile disturbances	RME	4	[2] a.1	135	[2] b.1	25	[2] c.1	0.022
			CTE	4	[2] a.1	135	[2] b.1	7	[1] c.2	0.0062
		USFS Forest Maintenance	RME	8	[3]	30	[3]	10	[3]	0.0039
			CTE	4	a.2	15	[3]	5	[3] c.3	0.00049
Outdoor Air During Woodchip/Mulch Disturbance Activities	Resident	Gardening/ Landscaping	RME	2.0	[4] a.3	40	[4] b.3	50	[4] c.4	0.0065
			CTE	1.0	[4] a.3	20	[4] b.3	25	[7] c.4	0.00082
Indoor Air During Woodstove Ash Disturbance Activities	Resident	Woodstove Ash Removal	RME	0.25	[5] a.6	48	[5] b.6	50	[4] c.4	0.00098
			CTE	0.25	[5] a.6	24	[5] b.6	25	[7] c.4	0.00024
Outdoor Air During Wildfires	Outdoor Worker (firefighter)	Air while fighting wildfires	RME	15	[3]	14	[3]	25	[3]	0.0086
			CTE	8	a.2	8	[3]	25	[3]	0.0026
	Resident	Ambient Air at Residence Impacted by Smoke	RME	24	a.5	5	[3]	50	[4] c.4	0.0098
			CTE	24	a.5	3	[3]	25	[7] c.4	0.0029

** TWF calculated as ET/24 · EF/365 · ED/70

Source Citations:

[1] EPA 2011. Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, September 2011.
[2] EPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December.
[3] Personal communication with United States Forest Service (USFS); email dated 6/24/14.
[4] Professional judgment using site specific considerations.
[5] Interviews with residents that use wood-burning stoves for home heating (CDM Smith 2012, Sampling and Analysis Plan/Quality Assurance Plan: Wood-Burning Stove Ash Removal Activity-Based Sampling, Libby Asbestos Site, Operable Unit 4. Revision 0 – November 2012).
[6] Input from local commercial logging operators in the Kootenai Valley. CDM Smith. 2012. Sampling and Analysis Plan/Quality Assurance Project Plan. 2012 Commercial Logging Activity-Based Sampling. August 2012.
[7] ATSDR 2001. Year 2000 Medical testing of Individuals Potentially Exposed to Asbestoform Minerals Associated with Vermiculite in Libby, Montana. A Report to the Community. August 23, 2001.

Source Notes:

a) Exposure Time [ET]

a.1 The default of 8 hours/day was adjusted by a factor of 0.5 assuming that a worker would not spend the entire day wood chipping.
a.2 Hours/day for CTE is assumed to be 1/2 RME value.
a.3 Hours/day performing landscaping are based on professional judgment [4].
a.4 Hours/day harvesting wood are site-specific values based on information from USFS [3]. CTE assumes 1/2 RME value.
a.5 Hours/day where smoke from a fire in OU3 reaches the community is a default value of 24 hours per day.
a.6 Hours/day cleaning woodstoves are based on interviews with residents that use wood burning stoves for heating; residents spend about 15 minutes per event.

TABLE 8-1

Exposure Parameters For Outdoor Air During Wood-Related Activities

Libby Asbestos Superfund Site

b) Exposure Frequency [EF]

b.1 Default exposure frequency estimates of 219 days/yr (CTE) or 225 days/yr (RME) for outdoor workers were adjusted to account for days when releases due to soil disturbance activities were unlikely either due to snow cover or high soil moisture content (i.e., November to March) (225 days - 90 days (18 weeks for 5 days per week)=135 days).

b.2 Days/year for CTE is assumed to be 1/2 RME value.

b.3 Days per year gardening is based on professional judgment considering site-specific conditions[4] - assumes garden work will take place during warmer months mainly between May and September for 1 to 2 days per week (total 20 to 40 days per year)

b.4 Days/year harvesting wood are site-specific based on input from USFS[3]. CTE assumes 1/2 RME value.

b.5 Days/year where smoke from a fire in OU3 reaches the community is based on input from USFS[3].

b.6 Days/year removing ash from woodstove are site specific based on interviews with residents [5]. CTE is 1/2 RME value.

b.7 RME Days/year adjusted to account for an area use factor of 0.1 (i.e., 10% of logging time is spent within OU3).

b.8 CTE Days/year adjusted to account for an area use factor of 0.05 (i.e., 5% of logging time is spent within OU3).

c) Exposure Duration [ED]

c.1 ED (years) is recommended default for workers in EPA 2002[2].

c.2 ED (years) is recommended mean value for workers in EPA 2011[1].

c.3 ED (years) for CTE is 1/2 of the RME value.

c.4 RME ED is based on professional judgment using site specific considerations.
The 2011 Exposure Factors Handbook provides statistics for years lived in current home based on U.S. Bureau of Census 2008 data. The 95th percentile was 46 years (EPA 2011 Table 16-90). Due to the nature of the Libby community, the RME ED was conservatively assumed to be 50 years. ATSDR (2001) provides site-specific data on the number of years individuals reside in Libby. The estimated median value is 23 years. The CTE ED was conservatively assumed to be 25 years.

c.5 Years spent harvesting wood are site-specific based on interviews with USFS[3]. CTE assumes 1/2 RME value.

Notes:

ATSDR - Agency for Toxic Substances and Disease Registry
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPA - environmental protection agency
ET - exposure time
OSWER - Office of Solid Waste and Emergency Response
OU - operable unit
RME - reasonable maximum exposure
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 8-2
Summary Statistics for Studies During Disturbances of Wood-Related Materials
Libby Asbestos Superfund Site

ABS Description	Wood Source*	N Samples Collected	N Samples with Detected PCME LA	PCME LA Air Conc. (s/cc)+		Mean Achieved Sensitivity (cc^{-1})
				Mean	Maximum	
Panel A: ABS Results During Residential Wood Harvesting						
Felling trees, de-limbing, cutting, stacking firewood	Forest, near	20	2	0.00014	0.0019	0.0082
	Forest, intermed.	20	11	0.0020	0.0060	0.0067
	Forest, far	22	1	0.00014	0.0030	0.011
Panel B: ABS Results During Commercial Logging Activities						
Hand-felling trees	~1 mile from mine	3	3	0.0034	0.0050	0.0012
Hooking/skidding, processing timber	~1 mile from mine	6	6	0.088	0.16	0.0087
Site restoration	~1 mile from mine	2	2	0.032	0.055	0.0036
Simulated milling (chipping)	~1 mile from mine	2	2	0.0068	0.0090	0.0017
Hand Felling	~4 miles from mine	3	1	0.0022	0.0065	0.0065
Skidding/Hooking	~4 miles from mine	4	1	0.00065	0.0026	0.0063
Mechanical Processing	~4 miles from mine	4	0	0	All ND	0.0064
Cutting slabs (pre-milling)	~4 miles from mine	8	0	0	All ND	0.0063
Simulated milling (chipping)	~4 miles from mine	8	0	0	All ND	0.0062
Site Restoration	~4 miles from mine	2	1	0.0040	0.0079	0.0065
Panel C: ABS Results During Wood Chipping Activities						
Chipping wood waste piles	various	6	0	0	All ND	0.0021
Panel D: ABS Results During Forest Maintenance Activities						
Road maintenance, tree thinning, forest surveying	Forest, near	30	0	0	All ND	0.013
	Forest, intermed.	30	5	0.00064	0.0064	0.012
	Forest, far	30	2	0.00020	0.0030	0.013
Panel E: ABS Results During Woodchip Disturbance Activities						
Woodchip/waste bark piles	various	16	0	0	All ND	0.0012
Digging/raking in woodchips	various	15	0	0	All ND	0.00060
Panel F: ABS Results During Woodstove Ash Disturbance Activities						
Emptying woodstove ash after burning firewood	~1 mile from mine	3	3	0.14	0.34	0.013
	Flower Creek	3	3	0.0074	0.018	0.0056
	Bear Creek	3	1	0.0029	0.0087	0.013
Panel G: Results During Authentic Wildfire						
Downwind stations during wildfire	Souse Gulch	2	0	0	All ND	0.00070
Ground-based firefighter activities	Souse Gulch	15	2	0.00031	0.0031	0.0017
Air-based wildfire suppression**	Souse Gulch	1	0	0	All ND	0.0024

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine.
Forest, far: greater than or equal to six miles from the mine
Flower Creek: approximately six miles from the mine
Bear Breek: approximately 10 miles from the mine

**Monitor was placed in the cockpit of the responding helicopter

Notes:
ABS - activity-based sampling
cc^{-1} - per cubic centimeter
Conc. - concentration
LA - Libby amphibole asbestos
N - number
ND - non-detect
PCME - phase contrast micrscopy-equivalent
s/cc - structures per cubic centimeter

TABLE 8-3
Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials
Libby Asbestos Superfund Site

Panel A: Risk Estimates Based on RME Exposure Parameters

Exposure Media	Receptor Population	Exposure/Disturbance Description*	Wood Source	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, during bark disturbances	Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	0.00014	10	15	40	0.0098	**2E-07**	**0.02**
			Forest, intermed.	0.0020	10	15	40	0.0098	**3E-06**	**0.2**
			Forest, far	0.00014	10	15	40	0.0098	**2E-07**	**0.01**
	Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	8	24	6	0.0019	**1E-06**	**0.07**
		Hooking/skidding, processing timber	~1 mile from mine	0.088	10	24	12	0.0047	**7E-05**	**5**
		Site restoration	~1 mile from mine	0.032	10	24	12	0.0047	**3E-05**	**2**
		Simulated milling (chipping)	~1 mile from mine	0.0068	10	24	12	0.0047	**5E-06**	**0.4**
		Hand Felling	~4 miles from mine	0.0022	8	24	6	0.0019	**7E-07**	**0.05**
		Skidding/Hooking	~4 miles from mine	0.00065	10	24	12	0.0047	**5E-07**	**0.03**
		Mechanical Processing	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
		Cutting slabs (pre-milling)	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
		Simulated milling (chipping)	~4 miles from mine	0	10	24	12	0.0047	**0E+00**	**0**
		Site Restoration	~4 miles from mine	0.0040	10	24	12	0.0047	**3E-06**	**0.2**
	Outdoor Worker (at landfill)	Chipping wood waste piles	various	0	4	135	25	0.022	**0E+00**	**0**
	Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	0	8	30	10	0.0039	**0E+00**	**0**
			Forest, intermed.	0.00064	8	30	10	0.0039	**4E-07**	**0.03**
			Forest, far	0.00020	8	30	10	0.0039	**1E-07**	**0.009**
Outdoor air, during woodchip/ mulch disturbances	Outdoor Worker (at OU5)	Woodchip/waste bark pile disturbances	various	0	4	135	25	0.022	**0E+00**	**0**
	Resident	Woodchip/mulch disturbances during gardening	various	0	2	40	50	0.0065	**0E+00**	**0**
Indoor Air, during wood-derived ash disturbances	Resident	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.25	48	50	0.00098	**2E-05**	**1**
			Flower Creek	0.0074	0.25	48	50	0.00098	**1E-06**	**0.08**
			Bear Breek	0.0029	0.25	48	50	0.00098	**5E-07**	**0.03**
Outdoor air, during bark disturbances in authentic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	0	24	5	50	0.0098	**0E+00**	**0**
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	0.00031	15	14	25	0.0086	**5E-07**	**0.03**
		Air-based wildfire suppression**	Souse Gulch	0	15	14	25	0.0086	**0E+00**	**0**

TABLE 8-3
Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials
Libby Asbestos Superfund Site

Panel B: Risk Estimates Based on CTE Exposure Parameters

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source	EPC	Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor air, during bark disturbances	Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	0.00014	5	5	20	0.00082	**2E-08**	**0.001**
			Forest, intermed.	0.0020	5	5	20	0.00082	**3E-07**	**0.02**
			Forest, far	0.00014	5	5	20	0.00082	**2E-08**	**0.001**
	Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	8	8	6	0.00063	**4E-07**	**0.02**
		Hooking/skidding, processing timber	~1 mile from mine	0.088	8	8	12	0.0013	**2E-05**	**1**
		Site restoration	~1 mile from mine	0.032	8	8	12	0.0013	**7E-06**	**0.4**
		Simulated milling (chipping)	~1 mile from mine	0.0068	8	8	12	0.0013	**1E-06**	**0.1**
		Hand Felling	~4 miles from mine	0.0022	8	8	6	0.0006	**2E-07**	**0.02**
		Skidding/Hooking	~4 miles from mine	0.00065	8	8	12	0.0013	**1E-07**	**0.009**
		Mechanical Processing	~4 miles from mine	0	8	8	12	0.0013	**0E+00**	**0**
		Cutting slabs (pre-milling)	~4 miles from mine	0	8	8	12	0.0013	**0E+00**	**0**
		Simulated milling (chipping)	~4 miles from mine	0	8	8	12	0.0013	**0E+00**	**0**
		Site Restoration	~4 miles from mine	0.0040	8	8	12	0.0013	**8E-07**	**0.06**
	Outdoor Worker (at landfill)	Chipping wood waste piles	various	0	4	90	25	0.015	**0E+00**	**0**
	Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	0	4	15	5	0.00049	**0E+00**	**0**
			Forest, intermed.	0.00064	4	15	5	0.00049	**5E-08**	**0.003**
			Forest, far	0.00020	4	15	5	0.00049	**2E-08**	**0.001**
Outdoor air, during woodchip/mulch disturbances	Outdoor Worker (at OU5)	Woodchip/waste bark pile disturbances	various	0	4	135	7	0.0062	**0E+00**	**0**
	Resident	Woodchip/mulch disturbances during gardening	various	0	1	20	25	0.00082	**0E+00**	**0**
Outdoor Air, during wood-derived ash disturbances	Resident	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.25	24	25	0.00024	**6E-06**	**0.4**
			Flower Creek	0.0074	0.25	24	25	0.00024	**3E-07**	**0.02**
			Bear Breek	0.0029	0.25	24	25	0.00024	**1E-07**	**0.008**
Outdoor air, during bark disturbances in authentic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	0	24	3	25	0.0029	**0E+00**	**0**
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	0.00031	8	8	25	0.0026	**1E-07**	**0.009**
		Air-based wildfire suppression**	Souse Gulch	0	8	8	25	0.0026	**0E+00**	**0**

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4

*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine.
Forest, far: greater than or equal to six miles from the mine
Flower Creek: approximately six miles from the mine
Bear Breek: approximately 10 miles from the mine

**Monitor was placed in the cockpit of the responding helicopter

Notes:
Conc. - concentration
CTE - central tendency exposure
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor
USFS - United States Forest Service

TABLE 10-1
Illustration of Poisson Uncertainty
Libby Asbestos Superfund Site

Panel A: Probability of Observing a Specified Number of Structures if λ is 3.72

N Structures Observed	Probability
0	2.4%
1	9.0%
2	16.8%
3	20.8%
4	19.3%
5	14.4%
6	8.9%
7	4.7%
8	2.2%
9	0.9%
10+	0.5%

Panel B: Example Calculations of Lower and Upper Bounds on Structure Counts and Concentration

Sample	Achieved Sensitivity (cc^{-1})	N Structures Observed	Air Conc. (s/cc)	LB – UB on Count*	LB – UB on Conc.(s/cc)
A-02987	0.01	0	0	0 – 2.51	0 – 0.025
B-19880	0.005	5	0.025	2.29 –10.51	0.011 – 0.053

*Based on 90% confidence interval (see Section 10.1.1 for equations)

Notes:
cc^{-1} – per cubic centimeter
Conc. – concentration
LB – lower bound
N - number
s/cc – structures per cubic centimeter
UB – upper bound
% - percent

TABLE 10-2
Examples of Estimated Risks Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Panel A: During Yard Soil Disturbances at Properties in OU4

Soil Concentration[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)+ Mean [a]	EPC (PCME LA s/cc)+ Estimated Upper-Bound [b]	RME Exposure Parameters ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Cancer Risk Mean	Cancer Risk Upper-Bound	Non-cancer HQ Mean	Non-cancer HQ Upper-Bound
Yards (Mowing, Raking, Digging)											
Bin A	**high intensity**	0.0040	0.0062	0.3	60	50	0.0015	1E-06	2E-06	0.07	0.1
	typical intensity	0.00011	0.0014	6.3	60	50	0.031	6E-07	7E-06	0.04	0.5
							TOTAL	**2E-06**	**9E-06**	**0.1**	**0.6**
Bin B1	**high intensity**	0.061	0.064	0.3	60	50	0.0015	2E-05	2E-05	1	1
	typical intensity	0.0024	0.0036	6.3	60	50	0.031	1E-05	2E-05	0.8	1
							TOTAL	**3E-05**	**3E-05**	**2**	**2**
Bin B2/C	**high intensity**	0.21	0.21	0.3	60	50	0.0015	5E-05	5E-05	3	3
	typical intensity	0.0080	0.0082	6.3	60	50	0.031	4E-05	4E-05	3	3
							TOTAL	**9E-05**	**1E-04**	**6**	**6**

Panel B: During Soil Disturbances in OU2

Receptor	Exposure Scenario	EPC (PCME LA s/cc)+ Mean [a]	EPC (PCME LA s/cc)+ Estimated Upper-Bound [b]	RME Exposure Parameters ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Cancer Risk Mean	Cancer Risk Upper-Bound	Non-cancer HQ Mean	Non-cancer HQ Upper-Bound
Outdoor Worker	Mowing Hwy 37 ROW	0	0.018	1	5	15	0.00012	0E+00	4E-07	0	0.02
Recreational Visitor	Hiking along Kootenai River	0	0.0048	2	10	50	0.0016	0E+00	1E-06	0	0.09

Panel C: During Recreational Visitor Soil Disturbances in OU3

Exposure Scenario	Exposure Area	EPC (PCME LA s/cc)+ Mean [a]	EPC (PCME LA s/cc)+ Estimated Upper-Bound [b]	RME Exposure Parameters ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Cancer Risk Mean	Cancer Risk Upper-Bound	Non-cancer HQ Mean	Non-cancer HQ Upper-Bound
Hiking	Rainy Creek	0.0093	0.011	6	48	50	0.023	4E-05	4E-05	2	3
	Forest, near	0.00050	0.0042	8	50	50	0.033	3E-06	2E-05	0.2	2
	Forest, intermed.	0.00065	0.0056	8	50	50	0.033	4E-06	3E-05	0.2	2
	Forest, far	0.00023	0.0052	8	50	50	0.033	1E-06	3E-05	0.08	2
ATV-riding	Forest, near	0.0014	0.0065	2	50	50	0.0082	2E-06	9E-06	0.1	0.6
	Forest, intermed.	0.00050	0.0062	2	50	50	0.0082	7E-07	9E-06	0.05	0.6
	Forest, far	0.00022	0.0060	2	50	50	0.0082	3E-07	8E-06	0.02	0.5
Campfire building/ burning	Forest, near	0.0023	0.0069	1	50	50	0.0041	2E-06	5E-06	0.1	0.3
	Forest, intermed.	0.0023	0.0065	1	50	50	0.0041	2E-06	4E-06	0.1	0.3
	Forest, far	0.00046	0.0060	1	50	50	0.0041	3E-07	4E-06	0.02	0.3
Driving	Forest, near	0.00027	0.025	1	50	50	0.0041	2E-07	2E-05	0.01	1
	Forest, intermed.	0	0.025	1	50	50	0.0041	0E+00	2E-05	0	1
	Forest, far	0	0.024	1	50	50	0.0041	0E+00	2E-05	0	1
Fishing/ boating	Kootenai River	0	0.00031	8	72	50	0.047	0E+00	2E-06	0	0.2

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ATV - all-terrain vehicle
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

TABLE 10-3
Effect of Changing the High Intensity Disturbance Frequency Assumption on Estimated Risks
Libby Asbestos Superfund Site

Panel A: High intensity disturbances account for 5% of yard disturbance time

Exposure Location (Scenario)	Soil Concentration[1]	Yard ABS Script Intensity	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4 Yards (Mowing, Raking, Digging)	Bin A	high intensity	0.0040	0.3	60	50	0.0015	**1E-06**	**0.07**
		typical intensity	0.00011	6.3	60	50	0.031	**6E-07**	**0.04**
							TOTAL	**2E-06**	**0.1**
	Bin B1	high intensity	0.061	0.3	60	50	0.0015	**2E-05**	**1**
		typical intensity	0.0024	6.3	60	50	0.031	**1E-05**	**0.8**
							TOTAL	**3E-05**	**2**
	Bin B2/C	high intensity	0.21	0.3	60	50	0.0015	**5E-05**	**3**
		typical intensity	0.0080	6.3	60	50	0.031	**4E-05**	**3**
							TOTAL	**9E-05**	**6**

Panel B: High intensity disturbances account for 20% of yard disturbance time

Exposure Location (Scenario)	Soil Concentration[1]	Yard ABS Script Intensity	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
			Mean Air Conc. (PCME LA s/cc)[+]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
OU4 Yards (Mowing, Raking, Digging)	Bin A	high intensity	0.0040	1.3	60	50	0.0064	**4E-06**	**0.3**
		typical intensity	0.00011	5.3	60	50	0.026	**5E-07**	**0.03**
							TOTAL	**5E-06**	**0.3**
	Bin B1	high intensity	0.061	1.3	60	50	0.0064	**7E-05**	**4**
		typical intensity	0.0024	5.3	60	50	0.026	**1E-05**	**0.7**
							TOTAL	**8E-05**	**5**
	Bin B2/C	high intensity	0.21	1.3	60	50	0.0064	**2E-04**	**10**
		typical intensity	0.0080	5.3	60	50	0.026	**4E-05**	**2**
							TOTAL	**3E-04**	**10**

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[1] PLM-VE Bin:
- A - ND
- B1 - Tr
- B2 - <1
- C - ≥ 1

Notes:
- ABS - activity-based sampling
- Conc. - concentration
- ED - exposure duration
- EF - exposure frequency
- EPC - exposure point concentration
- ET - exposure time
- HQ - hazard quotient
- LA - Libby amphibole asbestos
- OU - operable unit
- PCME - phase contrast microscopy - equivalent
- PLM-VE - polarized light microscopy - visual area estimation
- RME - reasonable maximum exposure
- s/cc - structures per cubic centimeter
- TWF - time-weighting factor
- % - percent

APPENDIX A

SCREENING LEVEL ASSESSMENT OF RISKS FROM ORAL EXPOSURE TO LIBBY AMPHIBOLE ASBESTOS

1.0 HEALTH EFFECTS OF ORAL EXPOSURE TO ASBESTOS

The U.S. Environmental Protection Agency (EPA) and Agency for Toxic Substances and Disease Registry (ATSDR) reviewed studies and reviews that have been performed to evaluate the health effects of oral exposure to asbestos. The following sections, adapted from EPA (1988) and ATSDR (2001), summarize the main findings.

1.1 Non-Cancer Effects

Studies in humans and animals indicate that ingestion of asbestos causes little or no risk of non-carcinogenic injury. Because ingested asbestos fibers are poorly absorbed, the tissue most highly exposed to ingested asbestos is the gastrointestinal tract epithelium. A few studies reported some histological or biochemical changes in gastrointestinal tract cells of rats chronically exposed to oral doses of asbestos, but, in an extensive series of lifetime dietary exposure studies in rats and Syrian hamsters, comprehensive microscopic evaluation of tissues and organs found no excess non-neoplastic lesions in the gastrointestinal epithelium or in other tissues or organs in animals exposed to daily doses as high as 500 to 830 milligrams of asbestos per kilogram body weight per day (mg/kg/day). The weight of evidence indicates that asbestos ingestion does not cause any significant non-carcinogenic effects in the gastrointestinal tract or other tissues.

1.2 Cancer Effects

A number of epidemiological studies of workers exposed to asbestos fibers in workplace air suggest that, in addition to increased risk of lung cancer and mesothelioma, workers may also have an increased risk of gastrointestinal cancers. Because the main route of exposure is inhalation, it is usually assumed that any effect of asbestos on the gastrointestinal tract is a consequence of mucociliary transport of fibers from the respiratory tract to the gastrointestinal tract. Because of these findings, a number of researchers have investigated the carcinogenic risk (especially the risk of gastrointestinal cancer) in humans and animals when exposure to asbestos occurs by the oral route.

1.2.1 Human Studies

A number of epidemiological studies have been conducted to determine if human cancer incidence is higher than expected in geographical areas where asbestos levels in drinking water are elevated (usually in the range of 1 to 300 million fibers per liter [MFL]). Most of these studies have detected increases, some of which were statistically significant, in cancer death or incidence rates at one or more tissue sites (mostly gastrointestinal) in populations exposed to elevated levels of asbestos in their drinking water. However, the magnitudes of the increases in cancer incidence are usually rather small and may be related to other risk factors such as smoking. In a review of data from eight independent epidemiological studies, it was concluded that the number of positive findings for neoplasms of the esophagus, stomach, pancreas, and prostate were unlikely to have been caused by chance alone (Marsh 1983). Similarly, Kanarek (1989) noted that there were relatively consistent findings for increased stomach and pancreatic cancer among the studies. Cantor (1997) reviewed the published studies and concluded that results from epidemiologic studies of populations exposed to high concentrations of asbestos in drinking water are inconsistent and are not adequate to evaluate cancer risk from asbestos

in drinking water, although some of the results are suggestive of elevated risks for gastric, kidney, and pancreatic cancer.

1.2.2 Animal Data

Early animal studies on gastrointestinal cancer from ingested asbestos were mostly negative, although some studies yielded increases in tumor frequency that were not statistically significant. More recently, a series of large scale, lifetime feeding studies were performed by the National Toxicology Program (NTP). These studies investigated the effects of several different types of asbestos, as summarized below.

Summary of NTP Oral Exposure Studies in Animals

Asbestos Type	Animal	NTP Conclusion	Citation
Amosite	Rat	Not carcinogenic	NTP 1990b
	Syrian hamster	Did not cause a carcinogenic response	NTP 1983
Crocidolite	Rat	Did not cause a carcinogenic response	NTP 1988
Tremolite	Rat	Did not cause a carcinogenic response	NTP 1990c
Chrysotile (short-range)	Rat	No evidence of carcinogenicity	NTP 1985
	Syrian hamster	Not carcinogenic	NTP 1990a
Chrysotile (intermediate-range)	Rat	Some evidence of carcinogenicity	NTP 1985
	Syrian hamster	Not carcinogenic	NTP 1990a

As shown, of 8 studies performed, seven were negative, including all studies of amphibole asbestos (amosite, crocidolite, tremolite). The only neoplastic response that was considered to be treatment related was an increase in the frequency of benign intestinal polyps in male rats (but not female rats or Syrian hamsters) exposed to intermediate-range chrysotile fibers (65 percent [%]) of fibers were longer than 10 micrometers [μm]). This effect was not observed following exposure to short-range chrysotile fibers (98% of fibers were shorter than 10 μm). Overall, the data were interpreted as providing "some evidence" of carcinogenicity for intermediate range chrysotile fibers.

2.0 QUANTITATIVE CANCER TOXICITY FACTORS

Three basic strategies are available for estimation of the oral slope factor for asbestos.

1. Epidemiological studies of cancer risk associated with exposure to asbestos in drinking water. However, as discussed above, none of the available epidemiological studies of cancer risk in humans exposed to asbestos in drinking water are suitable for estimating quantitative dose-response relationships (EPA 1988; ATSDR 2001).

2. Extrapolation from studies of workers exposed by inhalation. Both EPA and the National Academy of Sciences sought to estimate the risk of gastrointestinal cancer after oral exposure by extrapolating dose-response data from occupational studies (EPA 1980; NAS 1983). However, these potency estimates are rather uncertain because of uncertainty both in the level of inhalation exposure and in the extent of transfer of fibers from the lung to the gastrointestinal

(GI) tract, and this method for quantification of oral risk is not considered to be reliable (EPA 1988).

3. Extrapolation from animal studies. EPA (1988) determined that the most reliable study for estimation of oral cancer risk was the data on benign intestinal polyps in male rates exposed to intermediate length chrysotile (NTP 1985). Based on the data from this study, EPA (1988) calculated an upper bound on slope (q1*) of 1.4E-13 (TEM fibers per liter [f/L])$^{-1}$. Based on this, ingestion of 2 liters per day (L/day) of drinking water containing 1.0 MFL would result in an increased cancer risk to humans of about 1.4E-07. This corresponds to an oral slope factor (oSF) of 7.0E-08 per million fibers ingested.

The carcinogenic response in male rats exposed to intermediate range chrysotile was used by EPA to derive the maximum contaminant level (MCL) for asbestos in water (EPA 1985, 1991a). Because the intermediate range chrysotile was composed mainly of fibers longer than 10 μm, and because no carcinogenic response was observed in animals exposed to short range chrysotile (98% were less than 10 μm in length), EPA defined the MCL for asbestos as 7.1 million fibers longer than 10 μm per liter of water. This concentration is associated with an increased lifetime cancer risk of 1E-06.

It is important to note that the oSF derived from the intermediate range chrysotile study has not been approved for use at Superfund sites, and EPA's Integrated Risk Information System[1] (IRIS) does not identify any quantitative value for evaluation of oral exposure to asbestos. Nevertheless, this value and the associated MCL are judged to provide the most reliable basis for performing a screening level risk evaluation of oral exposures. It is considered likely that this oSF will overestimate any risks associated with oral exposure to Libby amphibole asbestos (LA), since no carcinogenic response was observed following exposure to any type of amphibole asbestos.

3.0 EXPOSURE AND RISK ASSESSMENT

There are a number of potential pathways by which individuals at the Libby Asbestos Superfund Site (Site) might be exposed to LA by the oral pathway, including the following:

- Ingestion surface water from area streams, ponds, or rivers
- Ingestion in groundwater from area wells
- Ingestion of fish caught from area streams or rivers
- Ingestion of meat from game animals harvested from the Site
- Incidental ingestion of contaminated soil or duff

The following sections provide screening level evaluations of these oral exposure pathways. In all cases, exposure concentrations are based on LA structures longer than 10 μm (designated as "LA>10").

[1] http://www.epa.gov/iris/subst/0371.htm

3.1 Exposure and Risk from Ingestion of Surface Water

LA Concentration in Surface Water

EPA has measured the concentration of LA in a number of surface water samples for streams, ponds, and rivers at the Site. **Table A-1** presents data on LA concentrations in surface water at various Site locations. As shown, LA structures are consistently observed in creeks and ponds near the former vermiculite mine (Operable Unit 3 [OU3]), including Carney Creek, Fleetwood Creek, lower Rainy Creek, and the on-site ponds and impoundments, but are rarely observed in upper Rainy Creek, the Kootenai River or its tributaries, or in reference streams/ponds. The overall mean concentration of LA>10 for surface water from the lower portion of the Rainy Creek drainage is 3.9 MFL, and is 0.01 MFL or less for the Kootenai River downstream of Rainy Creek and Kootenai River tributaries.

Surface Water Ingestion Rates

The streams and ponds of the lower Rainy Creek drainage are unlikely to be used for drinking water on a regular basis, but might occasionally be ingested by recreational visitors or workers. However, to be conservative, an intake rate of 2 L/day was assumed. This is the default reasonable maximum exposure (RME) drinking water intake rate used for evaluating residential exposures (EPA 1991b).

Estimated Cancer Risk from Surface Water Ingestion

Based on an exposure concentration of 3.9 MFL (lower Rainy Creek drainage) and a conservative intake rate of 2 L/day, the estimated excess cancer risk is 5E-07. This indicates that risk from ingestion of LA in lower Rainy Creek surface water is of low concern. Risk from ingestion of surface water from other areas, such as the Kootenai River and its tributaries, is substantially lower (surface water concentrations of LA are more than 300 times lower than in the lower Rainy Creek drainage).

3.2 Exposure and Risk from Ingestion of Groundwater

LA Concentration in Groundwater

EPA has measured the concentration of LA in a number of existing wells in OU3. **Table A-2** presents data on LA concentrations in groundwater for wells in OU3. As shown, LA>10 is only occasionally observed, usually at concentrations of 3 MFL or lower. The mean value across all wells is 0.7 MFL. However, for screening purposes, the highest concentration detected (3.0 MFL) is used to provide a conservative estimate of potential risks from hypothetical future ingestion of groundwater.

A total of 62 groundwater samples have been collected in OU4. The majority of these samples (N = 55) have been collected from the Lincoln County Landfill as part of the semiannual groundwater monitoring activities, while the remaining seven samples were collected from private residences. No groundwater samples collected in OU4 had LA structures detected that were longer than 10 μm.

Groundwater Ingestion Rates

Under present conditions, none of the groundwater wells in OU3 are used for drinking, but it is plausible that one or more might be used for drinking in the future. As with surface water, the most likely scenario is occasional ingestion by recreational visitors or workers. However, to be conservative, the default RME residential intake rate of 2 L/day was assumed (EPA 1991b).

Estimated Cancer Risk from Groundwater Ingestion

Based on an exposure concentration of 3.0 MFL and a conservative intake rate of 2 L/day, the estimated excess cancer risk is 4E-07. This indicates that risk from ingestion of LA in groundwater from wells in OU3 is of low concern.

3.3 Exposure and Risk from Ingestion of Fish

LA Concentration in Fish

Fish that reside in streams or rivers that are contaminated with LA may tend to take up fibers from the water or the sediment into their tissues, and ingestion of the fish might lead to exposure of area residents who catch and eat the fish. In order to investigate this possibility, EPA collected seven trout from the Mill Pond located near the mine. This site was selected because it is considered likely that tissue concentrations in fish from this location will be at the high-end of the concentration range, both because fish in the Mill Pond are relatively large (old), and because the concentration of LA in water and sediment in the Mill Pond contain higher levels of LA. Consequently, it is considered likely that tissue levels in these fish provide a conservative (high-end) estimate of what may occur in fish from other locations. These data are summarized in **Table A-3**. As indicated, the mean concentration of LA>10 in fish tissue from the Mill Pond was 4.2E+04 fibers per gram (wet weight) of tissue (f/g ww).

Fish Ingestion Rates

EPA's *Exposure Factors Handbook* (EPA 2011) provides data that may be used to estimate intake rates of fish by area residents. The recommended long-term average value for ingestion of fish caught by freshwater anglers is 5-12 grams (wet weight) per day (g ww/day), with 95% upper-bound values of 13-39 g ww/day (EPA 2011; Table 10-84). Based on this, an RME fish tissue intake rate of 39 g ww/day is assumed. Note that this is likely to be a conservative value because it assumes that 100% of all locally caught fish come from the lower Rainy Creek drainage. This is considered to be unlikely, and that only a small fraction of locally caught fish will come from this area.

Estimated Cancer Risk from Fish Ingestion

Based on an exposure concentration of 4.2E+04 f/g ww and a conservative intake rate of 39 g ww/day, the estimated excess cancer risk is 1E-07. This indicates that risk from ingestion of fish caught in the lower Rainy Creek drainage is of low concern. Risk from ingestion of fish from the Kootenai River is expected to be lower.

3.4 Exposure and Risk from Ingestion of Game

LA Concentration in Game

Game animals that reside at the Site may tend to take up fibers from environmental media into their tissues, and ingestion of the meat might lead to exposure of area residents who harvest the game animals. In order to investigate this possibility, EPA harvested a deer from near the mine area in OU3 and analyzed a number of tissue samples from this animal. As shown in **Table A-4**, no LA structures (of any size) were detected in any samples of muscle or organ tissue.

Game Ingestion Rates

EPA's *Exposure Factors Handbook* (EPA 2011) provides data that may be used to estimate intake rates of game by area residents. The recommended 95th percentile of game ingestion by people who hunt is 2.9 grams of tissue (wet weight) per gram of body weight per day (EPA 2011; Table 13-41). Assuming a default adult body weight of 70 kilograms (EPA 1991b), this is equivalent to an average daily intake of about 200 g ww/day. Assuming a typical meal includes about 0.75 pounds of game, this equates to an average of about four meals of game per week for a lifetime.

Estimated Cancer Risk from Game Ingestion

Because no LA was detected in any sample of deer meet, the best estimate of excess cancer risk is zero. If it were conservatively assumed that the average concentration of LA fibers was just below the mean achieved analytical sensitivity, the upper-bound LA>10 concentration estimate would be 8.4E+03 f/g ww, which would correspond to an excess cancer risk of 1E-07. Based on this, it is concluded that risk from ingestion of game harvested in OU3 is of low concern. Risk from ingestion of game harvested from outside OU3 is expected to be even lower.

3.5 Exposure and Risk from Ingestion of Soil

LA Concentration in Soil

At the Site, soil samples are usually analyzed for LA using polarized light microscopy (PLM), and results are reported as mass percent (%). As illustrated in **Figure A-1**, LA concentrations greater than 1% in soil and waste materials have been observed within the mined area, but outside the immediate mine areas the maximum observed value is Bin B2 (interpreted as an LA concentration between 0.2% and 1%), and many values are Bin B1 (interpreted as an LA concentration less than 0.2%) or Bin A (non-detect). Outside of OU3, soil concentrations are generally less than 1% (as this level has been used as a trigger for conducting soil removal actions [EPA 2003]). For the purposes of performing a screening level evaluation of soil ingestion exposures, a conservative mean soil exposure concentration of 1% is assumed.

Because risk is calculated from an estimate of ingested LA>10 fibers, it is necessary to convert a concentration of 1% in soil to units of LA>10 fibers per gram of soil (f/g). The first step is to convert soil

concentrations from mass percent to total[2] LA f/g, using the empiric relationship described by Januch *et al.* (2013):

Csoil (as f/g) = Csoil (as mass percent) · 3.6E+07

Thus, a concentration of 1% LA in soil is estimated to correspond to 3.7E+07 total LA f/g.

The second step is to estimate the fraction of the total LA fibers that are longer than 10 µm. The most reliable estimate of this fraction is derived from transmission electron microscopy (TEM) analyses of duff samples from OU3. For these duff samples, approximately 5% of all the LA structures recorded have a length greater than 10 µm (see **Figure A-2**). To be conservative, it was assumed that 10% of LA structures are longer than 10 µm. Based on this, the soil exposure concentration for LA>10 is 3.7E+06 f/g.

Soil Ingestion Rate

Most people do not intentionally ingest soil, but incidental intake may occur, mainly *via* hand to mouth contact. However, no site-specific data are available on the rate of soil ingestion that may occur by individuals at the Site. Default soil intake rate values used by EPA in human health risk assessments are as follows:

Default Soil Intake Rates Used in Human Health Risk Assessment

Exposed Population	Default RME Soil Intake Rate (mg/day)	
	Value	Source
Resident, child	200	EPA (1991b)
Resident, adult	100	EPA (1991b)
Outdoor worker	100	EPA (2002)
Construction worker	330	EPA (2002)

RME = reasonable maximum exposure
mg/day = milligrams of soil per day

The maximum default soil intake rate – 330 milligrams of soil per day (mg/day), based on a construction worker exposure scenario – is assumed. Based on an assumed exposure frequency of 50 days per year and an exposure duration of 50 years, this corresponds to a lifetime average intake rate of:

Lifetime average soil intake rate = 330 mg/day · (50 days/365 days) · (50 years /70 years)
= 32 mg/day

Risk from Ingestion of Soil

Based on an estimated lifetime average soil intake rate of 32 mg/day and an estimated soil concentration of 3.7E+06 LA>10 f/g, the estimated excess cancer risk is 2E-08. Based on this, it is concluded that risk from ingestion of soils with an LA concentration of 1% is of low concern; risk from ingestion of soils with LA concentrations less than 1% would be even lower.

[2] "Total" is defined as structures longer than 0.5 µm with an aspect ratio (length:width) of 3:1 or greater.

3.6 Exposure and Risk from Ingestion of Duff

LA Concentration in Duff

EPA has measured the concentration of LA in duff (forest litter) from numerous locations in OU3 and along the National Priorities List (NPL) boundary. As shown in **Figure A-3**, LA concentrations in duff near the mine may range as high as about 3E+09 f/g (total LA), but rapidly decline as a function of distance from the mine. To be conservative, a value of 3E+09 total LA fibers per gram (dry weight) of duff (f/g dw) is assumed, even though actual exposures in locations further from the mine would be much lower. As noted above, to be conservative, it was assumed that 10% of LA structures are longer than 10 µm (see **Figure A-2**). Based on this, the conservative estimate of LA>10 in duff is 3E+08 f/g dw.

Duff Ingestion Rate

Similar to soil, it is assumed that most people do not intentionally ingest duff, but that incidental ingestion may occur. However, no data are available on the ingestion rate of duff. In the absence of data, the duff intake rate is assumed to be equal to that for soil (32 mg/day).

Risk from Ingestion of Duff

Based on an estimated lifetime average duff intake rate of 32 mg/day and an estimated duff concentration of 3E+08 LA>10 f/g dw, the estimated excess cancer risk is 7E-07. Based on this, it is concluded that risk from ingestion of duff near the mine is of low concern; risk from ingestion of duff in locations further from the mine would be even lower.

4.0 SUMMARY

Based on conservative estimates of oral cancer potency and human exposure, screening level estimates of excess cancer risks from oral exposure to LA in surface water, groundwater, fish, game, soil, and duff are all below 1E-06 (see below), which is generally considered to be sufficiently low to be insignificant.

Exposure Scenario	**RME Excess Cancer Risk**
Ingestion of surface water	5E-07
Ingestion of groundwater	4E-07
Ingestion of fish	1E-07
Ingestion of game	1E-07
Ingestion of soil	2E-08
Ingestion of duff	7E-07

RME = reasonable maximum exposure

5.0 REFERENCES

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Table A-1
LA Concentrations in Surface Water

Location	Sampling Station	LA Water Concentration (LA>10 MFL)	
		Mean by Station	Overall Mean
Upper Rainy Creek	URC-1	0 (non-detect)	0.24
	URC-1A	0.0038	
	URC-2	0.39	
Lower Rainy Creek	LRC-1	1.1	3.9
	LRC-2	1.8	
	LRC-3	0.79	
	LRC-4	3.4	
	LRC-5	4.3	
	LRC-6	7.3	
Carney Creek/Pond	CC-1	0.26	2.2
	CC-2	2.7	
	CC-POND	1.8	
Fleetwood Creek/Pond	FC-1	0.34	10
	FC-2	0.45	
	FC-POND	17	
Tailings Pond	TP	6.7	4.5
	TP-OVERFLOW	0.19	
	TP-TOE1	0.35	
	TP-TOE2	0.40	
	UTP	1.9	
Mill Pond	MP	1.2	1.2
Kootenai River	Upstream of Rainy Creek	0.0085	0.0066
	Downstream of Rainy Creek	0.0062	
Kootenai River tributaries	Granite Creek	0.01	0.0036
	Libby Creek	0.01	
	Flower Creek	0 (non-detect)	
	Pipe Creek	0 (non-detect)	
	Fisher River	0 (non-detect)	
	Callahan Creek	0 (non-detect)	
OU3 Reference Creeks/Ponds+	Bobtail Creek tributary	0 (non-detect)	0.0048
	Noisy Creek	0.0040	
	Banana Lake	0.022	
	Tepee Pond 1	0 (non-detect)	
	Bobtail Pond	0 (non-detect)	

+ These creeks and ponds have been used as reference locations in the ecological assessments conducted for OU3
MFL = million fibers per liter
LA>10 = Libby amphibole asbestos fibers longer than 10 μm

Table A-2
LA Concentrations in Groundwater

Well ID	Sampling Event	Achieved Analytical Sensitivity (1/L)	LA Water Concentration (LA>10 MFL)
Well A	Round 1	2.5E+06	2.5
	Round 2	8.0E+05	0 (non-detect)
	Round 3	5.0E+04	0 (non-detect)
Well C	Round 1	5.0E+04	0 (non-detect)
	Round 2	5.0E+04	0 (non-detect)
	Round 3	5.0E+04	0 (non-detect)
Well D	Round 1	8.0E+05	0 (non-detect)
	Round 2	4.0E+05	0 (non-detect)
	Round 3	5.0E+04	0 (non-detect)
Well E	Round 1	1.0E+06	2.0
	Round 2	1.0E+06	3.0
	Round 3	5.0E+04	0.15
Well H	Round 1	1.3E+06	2.7
	Round 2	--	--
	Round 3	2.0E+05	0.20

MFL = million fibers per liter
LA>10 = Libby amphibole asbestos fibers longer than 10 μm
1/L = per liter
-- = not available

Table A-3
LA Concentrations in Fish Tissue

Sample ID	Species	Length (inches)	Weight (grams)	LA Tissue Concentration (LA>10 f/g ww)
MP-Fish-1	Rainbow Trout	9.6	140	3.5E+04
MP-Fish-2	Cutbow Trout	11.4	280	0 (non-detect)
MP-Fish-3	Cutthroat Trout	14.6	540	2.3E+04
MP-Fish-4	Cutbow Trout	14.6	560	3.5E+04
MP-Fish-5	Rainbow Trout	14.2	550	1.9E+05
MP-Fish-6	Cutbow Trout	13.0	450	1.2E+04
MP-Fish-7	Cutbow Trout	15.2	595	0 (non-detect)
	Mean	13.2	445	**4.2E+04**

f/g ww = fibers per gram of tissue (wet weight)
LA>10 = Libby amphibole asbestos fibers longer than 10 μm

Table A-4
LA Concentrations in Deer Tissue

Sample Description	Achieved Analytical Sensitivity (1/g ww)	LA Tissue Concentration (LA>10 f/g ww)
Heart	9.4E+03	0 (non-detect)
Kidney, Sample #1	2.5E+03	0 (non-detect)
Kidney, Sample #2	9.4E+03	0 (non-detect)
Inside Shoulder Muscle	9.4E+03	0 (non-detect)
Diaphragm, Sample #2	9.4E+03	0 (non-detect)
Diaphragm, Sample #1	9.4E+03	0 (non-detect)
Backstrap Muscle, Sample #1	9.4E+03	0 (non-detect)
Backstrap Muscle, Sample #2	9.4E+03	0 (non-detect)
Lung, Sample #1	2.5E+03	0 (non-detect)
Lung, Sample #2	2.5E+03	0 (non-detect)
Liver, Sample #1	9.4E+03	0 (non-detect)
Liver, Sample #2	1.9E+04	0 (non-detect)
Mean	**8.4E+03**	**0 (non-detect)**

f/g ww = fibers per gram of tissue (wet weight)
1/g ww = per gram of tissue (wet weight)
LA>10 = Libby amphibole asbestos fibers longer than 10 µm

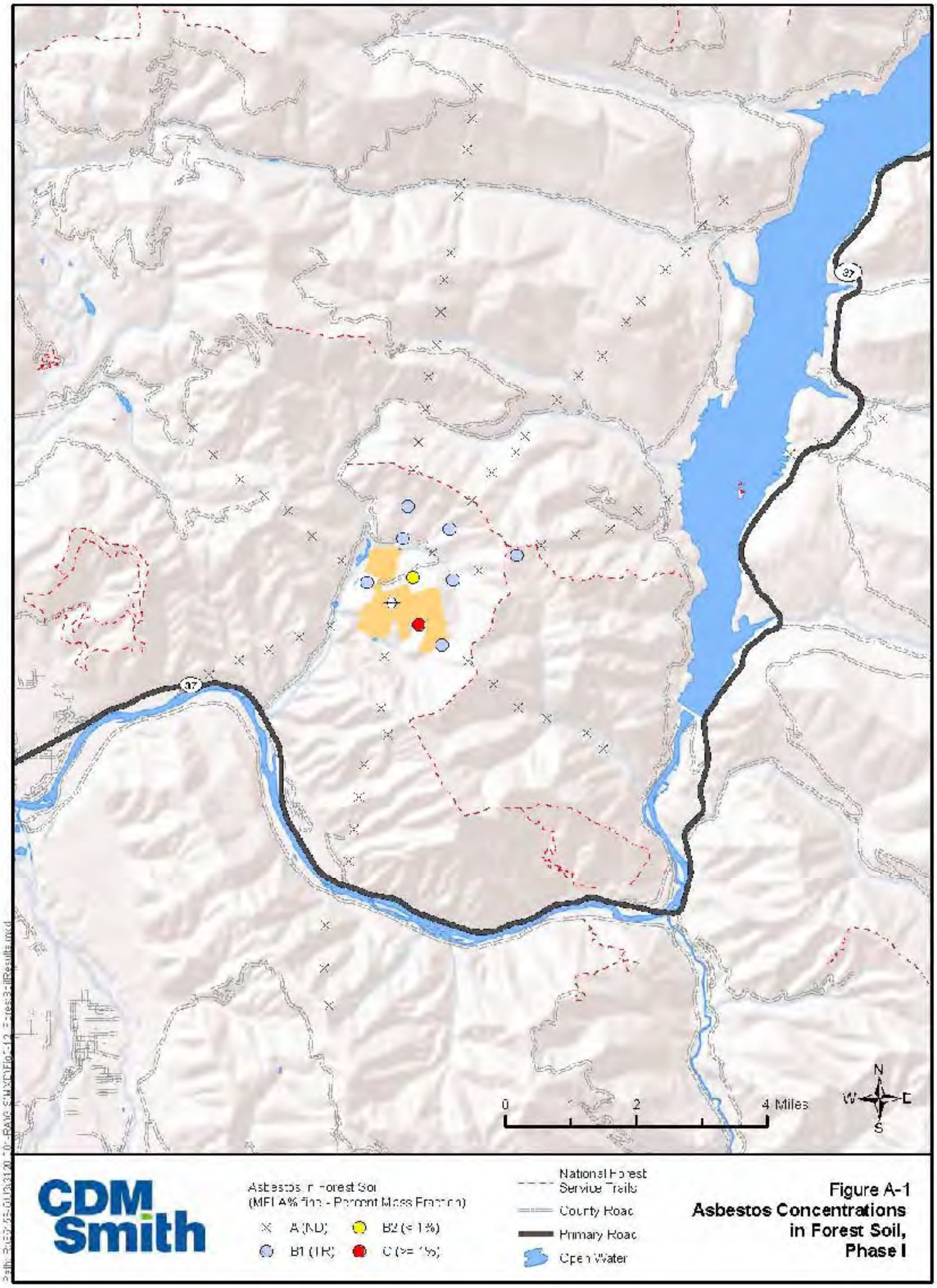
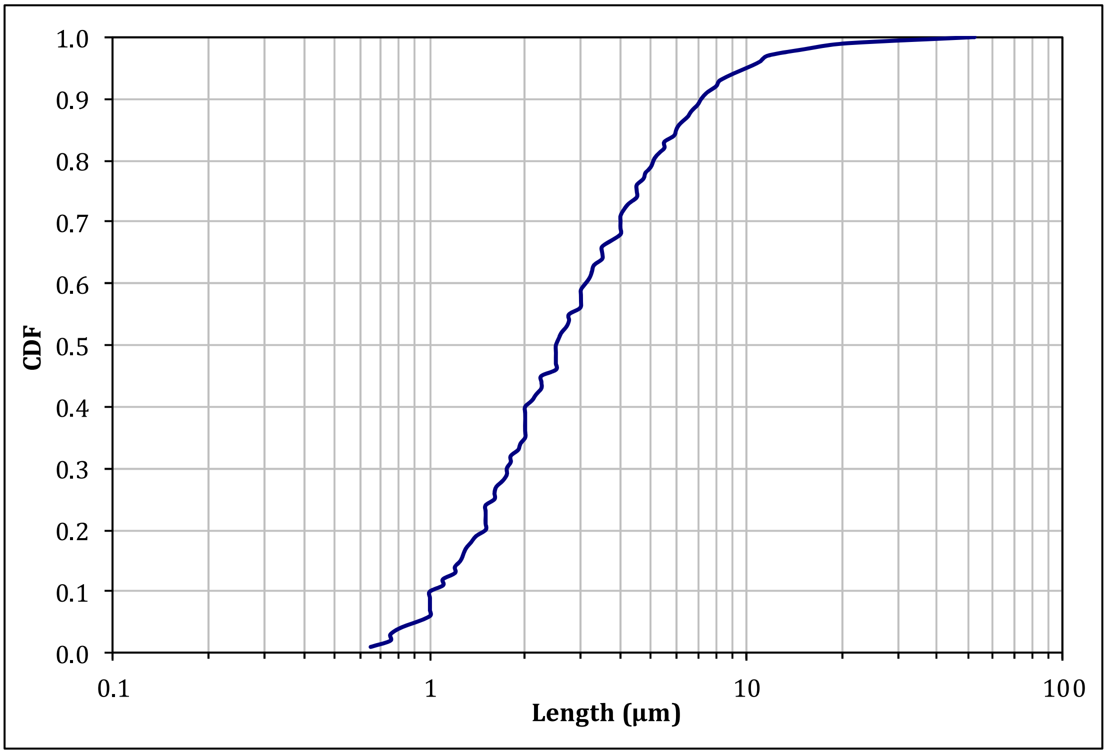


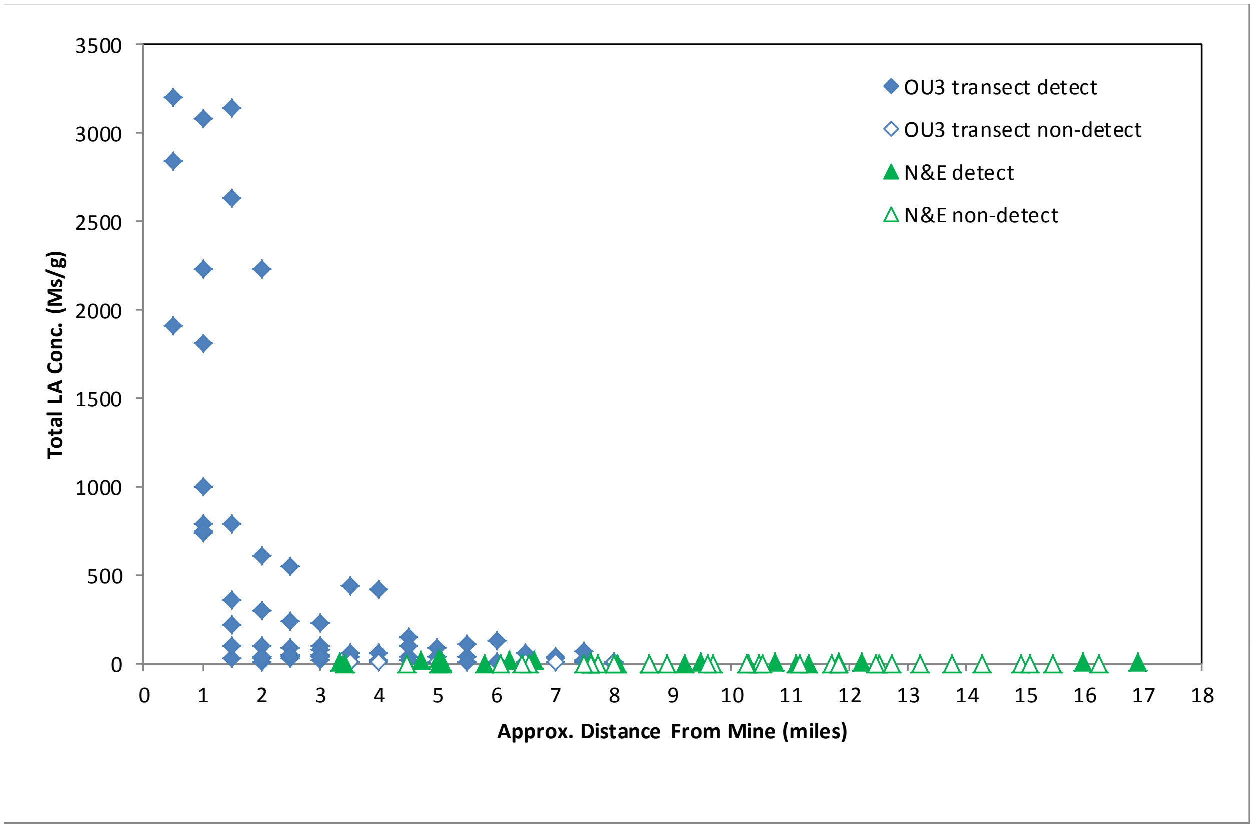
Figure A-1
Asbestos Concentrations in Forest Soil, Phase I

Figure A-2
Size Distribution of LA Structures Observed in Duff Samples from OU3



Graph is based on 1,547 total LA structures recorded for duff samples collected in OU3.

Figure A-3
Duff Concentrations as a Function of Distance from the Mine



LA = Libby amphibole
Ms/g = million structures per gram of duff
N&E = Nature & Extent Forest Study
OU3 = Operable Unit 3 Phase I Study

APPENDIX B

BASIC CONCEPTS OF ASBESTOS SAMPLING, ANALYSIS, AND DATA REDUCTION FOR RISK ASSESSMENT PURPOSES

1.0 INTRODUCTION

In many ways, the issues associated with sampling and analysis of asbestos in air are the same as for other analytes in other media. However, there are a number of issues that are unique to asbestos, and understanding these issues is key to proper use and interpretation of data for site characterization and risk assessment at asbestos-contaminated sites. This appendix provides basic information that explains how to interpret and utilize data on asbestos concentrations in air that are collected during site investigations.

2.0 BASICS OF ASBESTOS AIR SAMPLING AND ANALYSIS

The concentration of asbestos in air is usually estimated by drawing a known volume of air through a filter and counting the number of asbestos structures[1] on the filter using some appropriate microscopic technique. The concentration is then calculated as follows:

$$C = N_t / V_t \qquad \textbf{[Eqn. 1]}$$

where:

C = Concentration of asbestos in the air drawn through the filter (structures per cubic centimeter, s/cc)
N_t = Total number of asbestos structures on filter (structures, s)
V_t = Total volume of air drawn through filter (cubic centimeter, cc)

Counting structures on the filter may be achieved using several different types of microscope, but the U.S. Environmental Protection Agency (EPA) generally recommends using transmission electron microscopy (TEM) because this technique has the ability to clearly distinguish asbestos from non-asbestos structures, and to classify different types of asbestos.

In air sampling for asbestos, the filter that is used is usually about 25-millimeters (mm) in diameter, and has an effective filter area (the area of filter through which air can pass) of about 360 to 385 square millimeters (mm^2), depending on the filter device. The filter is usually made of mixed cellulose ester (MCE) and can have effective pore sizes ranging from 0.2 to 0.8 micrometers (μm). In most cases, samples of air are collected using pore sizes of 0.45 or 0.8 μm to avoid excess backpressure on the filter.

After air is drawn through the filter, a wedge is cut from the filter and this is placed on a glass slide. This is referred to as “direct” preparation. In some cases, the filter may be too heavily loaded with particulate matter to allow a reliable “direct” examination of the filter. In such cases, the filter may be evaluated

[1] The basic physical unit of asbestos is a fiber. However, in some samples, fibers may occur in complex structures classified as bundles, clusters, or matrix particles. International Organization of Standardization (ISO) method 10312 provides rules for quantifying the contribution of these complex structures to concentration estimates. For simplicity, the term “structure” is used here to include both individual fibers as well as the more complex structures.

using an "indirect" preparation technique, where the material on the original (primary) filter is suspended in water, and a fraction of the water suspension is filtered through a new (secondary) filter.

The wedge of filter (either primary or secondary) is collapsed by exposure to a solvent (e.g., acetone), and the surface of the collapsed filter is etched to help expose the asbestos structures. This collapsed and etched filter is then carbon-coated, and several pieces of the carbon-coated material are transferred onto small copper grids. Each grid is about 3-mm in size (either round or square), and contains a very fine copper mesh in the center. The copper grid bars (usually about 20 μm wide) are opaque, but the areas between the grid bars (the grid openings [GOs]) are transparent. The size of each GO is usually about 0.1-mm x 0.1-mm, corresponding to an area of about 0.01 mm^2 (depending on manufacturer). During analysis, a number of GOs (selected at random) are examined in the TEM instrument, and the number of structures observed in each GO is recorded.

The raw data from each analysis consists of the number of asbestos structures observed and the number of GOs examined. From these data, the concentration of asbestos in the sample is calculated as follows:

$$C = N_{obs} \cdot EFA / (GOx \cdot Ago \cdot V_t \cdot 1000 \cdot F) \qquad \textbf{[Eqn. 2]}$$

where:

C	=	Asbestos concentration in air (s/cc)
N_{obs}	=	Number of structures observed in the analysis of the grid openings
EFA	=	Effective filter area (mm^2)
GOx	=	Number of grid openings examined
Ago	=	Area of one grid opening (mm^2)
V_t	=	Total volume of air drawn through the filter (liters [L])
1000	=	Conversion factor from L to cc
F	=	Fraction of the material on the primary filter applied to the secondary filter (if an indirect preparation was used). If a direct preparation was used, F = 1.0.

For convenience, Equation 2 is often written as:

$$C = N_{obs} \cdot S \qquad \textbf{[Eqn. 3]}$$

where S = analytical sensitivity, which has units of 1/cc (cc^{-1}). The value of S is given by:

$$S = EFA / (GOx \cdot Ago \cdot V_t \cdot 1000 \cdot F) \qquad \textbf{[Eqn. 4]}$$

Note that S is the inverse of the volume of air that passed through the area of filter analyzed:

$$S = 1/V_a$$

$$V_a = 1/S$$

where:

V_a = Volume of air that passed through the area of filter analyzed (cc)
= $V_t \cdot 1000 \cdot (GOx \cdot Ago \cdot F / EFA)$

Consequently, we may also express concentration as follows:

$C = N_{obs} / V_a$ **[Eqn. 5]**

3.0 POISSON STATISTICS

If it were possible to actually examine the entire filter under the microscope, it would be possible to count exactly the total number of structures present on the filter. Hence, the true concentration in the air passed through the filter would be known with certainty, and there would be no need to consider any type of statistics. However, due to time and cost constraints, in a typical TEM analysis, only a tiny fraction of the filter is actually examined. For example, if a total of 50 GOs were examined, this would usually correspond to an area of about 0.5 mm^2, which is only a little more than 0.1 percent (%) of the total filter area.

This means that the number of structures that are observed during any specific analysis of a filter is a random sample of the whole population of all structures on the filter, and the sample observed in any one analysis may or may not be a good representation of the whole. This means we have to consider the *statistical uncertainty* in the results for that sample.

Perhaps the best way to understand the problem is to consider an example. Assume we draw a volume of 200 L (200,000 cc) of air through a filter. Assume the true concentration of asbestos in the air is 0.0030 s/cc. Based on these assumptions, the total number of structures on the filter is:

$N_t = 0.0030 \text{ s/cc} \cdot 200{,}000 \text{ cc} = 600 \text{ structures}$

Assuming an EFA of 360 mm^2, the structure loading on the filter is:

$\text{Loading} = 600 \text{ structures} / 360 \text{ mm}^2 = 1.67 \text{ s/mm}^2$

Assume we analyze a total of 25 GOs, each with an area of 0.01 mm^2. Under these conditions, the expected count (often indicated by λ, the Greek letter lambda) of asbestos structures is:

$\lambda = (25 \text{ GO}) \cdot (0.01 \text{ mm}^2/ \text{GO}) \cdot (1.67 \text{ s/mm}^2) = 0.417 \text{ structures}$

That is, if we analyze this filter several times by counting 25 GOs each time, on average we would expect to see 0.417 structures. However, it is obvious that in any one specific analysis we will never see 0.417 structures. Rather, we will see some integer number (0, 1, 2, 3, etc.). The relative probability of seeing any specified count "x" is given by the Poisson distribution:

Probability of seeing a count of "x" = Poisson (x, λ)

The following table gives the Poisson distribution for this particular example (λ = 0.417 structures):

Count	Probability
0	65.9%
1	27.5%
2	5.7%
3	0.8%
4	0.1%
5	0.01%

Thus, if we count 25 GOs selected at random, there is a 65.9% chance we will see zero structures, a 27.5% chance we will see one structure, a 5.7% chance we will see two structures, and less than a 1% chance we will see three or more structures.

Let's say that in our analysis of this sample we saw 1 structure in 25 GOs. Based on this, we would estimate the concentration to be:

$C = N_{obs} \cdot S$
$N_{obs} = 1$
$S = 360\ mm^2 / (25\ GO \cdot 0.01\ mm^2/GO \cdot 200\ L \cdot 1{,}000\ cc/L \cdot 1.0) = 0.0072\ (cc)^{-1}$
$C = 0.0072$ s/cc

Note that this value is substantially higher than the true concentration (0.0030 s/cc). Likewise, if we had seen a count of zero (a 66.2% chance), we would have said the concentration is zero (substantially lower than the true value). Based on this, it is clear that a measured (observed) estimate of concentration is unlikely to be identical with "truth", and the true concentration might be either higher or lower than our estimate. The following section discusses how to quantify the uncertainty around any particular concentration estimate.

4.0 CHARACTERIZING UNCERTAINTY IN INDIVIDUAL SAMPLES

There are a number of different statistical methods for estimating the confidence interval around a Poisson count. For example, the International Organization of Standardization (ISO) Method 10312:1995(E) (ISO 1995) calculates the bounds as follows:

5% Lower Bound on Count = $0.5 \cdot$ CHISQ.INV$(0.05, 2 \cdot N_{obs})$
95% Upper Bound on Count = $0.5 \cdot$ CHISQ.INV$(0.95, 2 \cdot N_{obs} + 2)$

where CHISQ.INV is the inverse chi-squared distribution function. Because this method tends to overestimate the confidence interval for small values of N_{obs}, EPA has selected the method recommended by Box and Tiao (1973) for use at the Libby Asbestos Superfund Site:

5% Lower Bound on Count = 0.5 · CHISQ.INV(0.05, $2 \cdot N_{obs}$ + 1) **[Eqn. 6]**
95% Upper Bound on Count = 0.5 · CHISQ.INV(0.95, $2 \cdot N_{obs}$ + 1) **[Eqn. 7]**

Table 1 shows the lower and upper bounds for a range of observed count values (N_{obs}), and **Figure 1** plots the ratio of the 5^{th} and 95^{th} uncertainty bounds to N_{obs} as a function of N_{obs}. As shown, relative uncertainty (lower or upper bound divided by N_{obs}) is highest for samples with small counts, and decreases as count increases.

In the example above (N_{obs} = 1 structure), the bounds on count based on Box and Tiao are:

5% Lower Bound on Count = 0.176 structures
95% Upper Bound on Count = 3.907 structures

Multiplying the bounds on count by the sensitivity (0.0072 cc^{-1}) yields the bounds on concentration:

5% Lower Bound on Concentration = 0.176 · 0.0072 = 0.0013 s/cc
95% Upper Bound on Concentration = 3.907 · 0.0072 = 0.0281 s/cc

That is, there is less than a 5% chance that the true concentration is lower than 0.0013 s/cc, and there is less than a 5% chance that the true concentration is higher than 0.0281 s/cc.

5.0 DETECT vs NON-DETECT

In general, a sample is ranked as a detect if there is high confidence that the analyte of concern is present in the sample. In the case of asbestos, this means that there must be high confidence that any structures observed during the analysis actually arose from the sample and were not attributable to "background".

Begin by considering the case where unused filters (i.e., blank filters) have no asbestos structures on them. That is, no matter how many GOs we count for blank filters, we will never see even one asbestos structure. In this case, if we see one structure in a field sample (a filter that has had air passed through it), the structure must be derived from the air, and the sample is a detect.

What if blank filters have a non-zero number of structures on them? This situation is addressed in ASTM 6620-06, *Standard Practice for Asbestos Detection Limit Based on Counts* (ASTM 2010). In this approach, a sample is declared to be a detect if the number of structures observed in the analysis of the field sample is higher than the high end of the number of structures that might be observed in any random examination of an equal area of a blank filter. This determination is performed as follows:

Step 1. Assemble the results for all relevant blank samples and compute the value of L_0, which is the average number of countable asbestos structures observed per mm^2 on filter blanks:

$L_b = N_b / A_b$ **[Eqn. 8]**

where:

L_b = Background loading of countable structures (s/mm^2)
N_b = Total number of countable structures observed in the analysis of filter blanks (s)
A_b = Total area (mm^2) of filter blanks evaluated (=∑ GOs counted · Ago)

Step 2. Compute λ_0, which is the average number (count) of background asbestos structures that would be expected during examination of an area A_s (mm^2) from a field sample:

$$\lambda_0 = L_b \cdot A_s \qquad \textbf{[Eqn. 9]}$$

Note that the value of A_s (and hence the expected count λ_0) may vary between field samples, depending on the total number of GOs counted and the area of the GOs (A_s = GOs counted · Ago).

Step 3. Based on the average count (λ_0) of background structures from Step 2, use the Poisson distribution to find x0, which is the count of background structures that would be observed in no more than 5% of a set of random observations of area A_s in field blanks. **Table 2** (taken from ASTM 6620-06) shows the value of x0 for average background counts (λ_0) ranging from zero up to about 2.6 structures.

Step 4: Compare the observed number (N_{obs}) of structures from area A_s of the field sample to x0. If N_{obs} > x0, conclude that the number of structures observed in the field sample is higher than background and rank the sample as a detect. If $N_{obs} \leq$ x0, then conclude that the observed number of structures in the field sample could be attributable to background, and rank the sample as a non-detect. Note that if the average expected count of background structures (λ_0) is small (≤ 0.05), then x0 is zero and any field sample with an observed count of one or more structures should be ranked as a detect.

EXAMPLE:

Step 1: Assume that we have analyzed 25 GOs in each of 100 filter blanks, and we have observed a total of 4 structures. Based on this:

N_b = 4 structures
A_b = 25 GO/blank · 100 blanks · 0.01 mm^2/GO = 25 mm^2
$L_b = N_b / A_b$ = 4 structures / 25 mm^2 = 0.16 s/mm^2

Step 2: Assume we have collected a field sample for which we have analyzed a total of 50 GOs. Based on this,

A_s = 50 GOs · 0.01 mm^2/GO = 0.5 mm^2
$\lambda_0 = L_b \cdot A_s$ = 0.16 s/mm^2 · 0.5 mm^2 = 0.08 structures

Steps 3 and 4: Using **Table 2**, we can see that x0 = 1 for all values of λ_0 between 0.05 and 0.35. Because our value of λ_0 is in this range, we conclude that there is less than a 5% chance we will

see more than 1 background structure in any random analysis of 50 GOs. Therefore, if we see two or more structures in our analysis of this field sample, we will rank the sample as a detect.

In the past, the occurrence of countable structures on blank filters was high enough that it could not be ignored. However, modern filters are manufactured in a way such that asbestos structures are quite rare when analysis is by TEM, since TEM can distinguish asbestos from other types of structures that might be present. Based on this, it is likely the value of L_b will be zero or very close to zero in most cases. For example, at the Libby Superfund site, more than 7,600 TEM analyses of blank filters have been performed (CDM Smith 2012, 2014), with the following results:

N_b = 12 s
A_b = 1,149 mm^2
L_b = 0.010 s/mm^2
x0 = 0

In this case (x0 = 0), any field sample with one or more observed asbestos structures is a detect, and the calculation of concentration can simply ignore any corrections for background contribution.

6.0 DETECTION LIMIT

In analytical chemistry, the detection limit (DL), also referred to as the limit of detection (LOD), is usually defined as a concentration that can be recognized with confidence to be greater than zero. This approach is based on the fact that most analytical instruments have a non-zero signal when a sample blank is analyzed, and that this non-zero signal is variable. The DL is a concentration that consistently generates a signal that is higher than the high-end of the range of signals generated by blank samples. In asbestos analysis, the "signal" that is measured is not electronic, but is a count of asbestos structures observed during a visual examination of a filter through a microscope.

Let's begin by considering an example. Assume we pass 200 L (200,000 cc) of air through a clean filter (background loading = 0), and we analyze 10 GOs (a total of 0.10 mm^2 of filter). The red line in **Figure 2** shows the probability of observing one or more structures (i.e., of detecting the presence of asbestos) in our analysis as a function of the concentration in the air. As seen, we stand very little chance of detecting even one structure if the concentration is lower than about 0.001 s/cc, while we are nearly certain we will detect one or more structures if the concentration is 0.1 s/cc or higher. In the range between 0.001 and 0.1 s/cc (a 100-fold range), the probability of detection increases from low to high as concentration increases.

So, what is the "detection limit" in this example? To answer that, we have to specify some probability of detecting asbestos if it is present. For example, if we decide to define the detection limit as a concentration that will be detected 95% of the time, the detection limit in this case would be about 0.054 s/cc. Note that identifying 0.054 s/cc as the "detection limit" does not mean we cannot detect a sample whose concentration is lower than 0.054 s/cc. Indeed, we can detect samples up to 50-fold lower, although the probability of detection decreases as concentration decreases below the detection limit.

Now, let's re-analyze the sample, except this time we count 100 GOs rather than 10, as shown by the blue line in **Figure 2**. By increasing the number of GOs analyzed by a factor of 10, the detection frequency curve shifts left by a factor of 10. Now we can nearly always detect a concentration of 0.01 s/cc, and we may be able to occasionally detect samples as low as 0.0001 s/cc. The detection limit (95% detection probability) for this analytical strategy is 0.0054 s/cc (10-fold lower than before). This emphasizes the key point: *there is no inherent detection limit in asbestos analysis*. We can (at least in concept) achieve any detection limit of our choice, simply by analyzing more and more GOs (more and more volume).

Once a probability value is chosen to define the DL, and assuming the background loading on the filter is zero or negligible, the basic equation for calculating the DL is as follows:

$$DL = -S \cdot \ln(1 - \text{probability}) \qquad \textbf{[Eqn. 10]}$$

The following table shows the results for a series of alternative values of probability of detection:

Probability of Detection	DL/S
0.95	2.996
0.90	2.303
0.80	1.609
0.70	1.204
0.63	1.000
0.50	0.693

The actual DL of a sample is then computed by multiplying the appropriate value of DL/S in the table above by the sample-specific value of S (which in turn depends on volume of air drawn through the filter and the number of GOs analyzed).

As shown, if DL is defined as a concentration that will be detected at least 95% of the time, the value of the DL is equal to 2.996 times the analytical sensitivity (S). This is the approach recommended by ISO (1995)[2] as well as ASTM (2010). As noted above, this is the lowest concentration that can be detected in nearly every case. It does <u>not</u> mean that lower concentrations cannot be detected, or that samples with 3, 2, or 1 observed structures should be considered "non-detects" or qualified as being uncertain.

Also note that some people simply assume that the analytical sensitivity (S) of an asbestos analysis is the same as the DL for that sample. However, as shown in the table above, this is true only if we choose to define the DL as a concentration that will be detected 63% of the time.

[2] ISO 10312 states that the limit of detection is based on "the upper 95% confidence limit on the Poisson distribution for a count of zero structures. In the absence of background, this is equal to 2.99 times the analytical sensitivity." However, this description is somewhat misleading because it confuses the Poisson uncertainty around a count of zero with a concentration that has a 95% probability of yielding a count of 1 or more. Nevertheless, the value is correct.

7.0 DEALING WITH MULTIPLE SAMPLES

7.1 Overview

All of the text above has focused on dealing with *individual samples*. However, human exposure and health risk can almost never be reliably characterized based on a single sample. Rather, the concentration of asbestos in air that a person is exposed to is likely to vary from place to place and from time to time, and risk-management decisions are generally based on the risk associated with the *long-term average* exposure concentration, not the risk from any one specific exposure event. In order to estimate the long-term average exposure concentration, it is necessary to collect multiple samples that provide measures of concentration that are realistic and representative over space and time.

7.2 Deriving the Best Estimate of the Mean of an Asbestos Data Set

By analogy with the process that is usually followed for other (non-asbestos) chemicals, some people assume that when the mean of a data set is calculated, all "non-detects" (i.e., samples with a count of zero) should be assigned a surrogate value greater than zero to account for the fact that the true concentration in the sample is probably not a true zero. While it is correct that the true concentration of an asbestos sample with zero counts may be greater than zero (see Section 4, above), it is not correct to assign some surrogate value (e.g., S or ½ S) to non-detects when computing the best estimate of the sample mean. Rather, the best estimate is obtained when all non-detects are evaluated using a concentration of zero (Cameron and Pravin 2007; Haas *et al.* 1999; EPA 1999, 2008).

If any value greater than zero is assigned to these samples, this will cause the estimate of the sample mean to be biased high. This is illustrated in **Figure 3**. In this example (generated using Monte Carlo simulation), a set of 100 samples is drawn from a lognormal distribution and analyzed with a range of alternative analytical sensitivities that yield detection frequencies ranging from about 15% up to about 90%. For each data set, the sample mean is divided by the true mean to generate a ratio. The upper panel shows the average and range (minimum to maximum) of the ratio values that are obtained when non-detects are evaluated as zero. As seen, regardless of the detection frequency, the expected value of the ratio is 1.0 (i.e., the expected mean is equal to the true mean). That is, treatment of non-detects as zero does not bias the results low.

The lower panel shows what happens when non-detects are assigned a non-zero surrogate value. In this example, the surrogate assigned is 0.5 times the analytical sensitivity (½ S). As seen, for cases where a high fraction of the samples are non-detects, a strong and substantial bias towards overestimation of the mean occurs. As expected, the magnitude of the bias decreases as the fraction of non-detects decreases.

So, the principle is clear: *when calculating the mean of an asbestos data set, the best estimate is obtained by treating all non-detects as zero*. These are valid samples and must be utilized as such, without adjustment.

7.3 Estimating the Uncertainty Around a Sample Mean

Ideally, the mean concentration for a data set, calculated as described above, would be equal to the true long-term average exposure concentration. However, due to random variation in both sampling and analysis, the average across multiple samples might be either higher or lower than the true long-term average. For this reason, EPA generally recommends that exposure and risk be calculated using the 95% upper confidence limit (95UCL) on the sample mean rather than the sample mean itself. This helps ensure that there is no more than a 5% chance that the actual exposure concentration will be underestimated, which in turn helps limit the probability of making a false negative decision error (declaring a site safe when it is in fact not safe).

To help with this process, EPA has developed a software application (ProUCL) to assist with the calculation of 95UCL values (EPA 2013). However, the equations and functions in ProUCL are not designed for asbestos data sets and application of ProUCL to asbestos data sets is not recommended (EPA 2008). This is because the variability between samples depends both on sampling variability (authentic differences between different samples) as well as Poisson counting uncertainty in each sample (Brattin *et al.* 2012). Because of this, EPA (2008) recommends that, until a statistical method is selected and validated by EPA for estimation of the 95UCL of an asbestos data set, risks from exposure to asbestos be calculated based on the best estimate of the mean concentration, recognizing that the sample mean may be either higher or lower than the true long-term average exposure concentration.

Nevertheless, in the case of data sets that are dominated by non-detects, especially a data set consisting of all non-detects, it is rather dissatisfying to declare that the best estimate of concentration is zero (and hence risk is zero). For this reason, as part of the uncertainty analysis, it may be useful to calculate an "upper-bound" on the sample mean by assigning a surrogate value (½ S or S) to non-detects. This approach is not statistically rigorous, but does yield a concentration value that is likely to be higher than the true mean concentration for that data set (see **Figure 3**).

8.0 SUMMARY

There are a number of key concepts that must be understood in order to properly interpret and utilize data on asbestos concentrations in air. The most important are summarized below:

1. Because of how asbestos is measured (by counting structures under a microscope), the analytical measurement error for asbestos samples is usually higher than for most other (non-asbestos) analytes.

2. The uncertainty around any specific measurement of asbestos concentration is highest when structure counts are low (e.g., 0 to 5 structures), and diminishes as structure counts increase.

3. If samples are collected on filters that have a negligible occurrence of countable "background" asbestos structures, then the occurrence of even one asbestos structure ranks the sample as a detect. This is likely to be the case with most modern-day filters analyzed by TEM and is true for the Libby Asbestos Superfund Site.

4. The "detection limit" in asbestos analysis is a not a sharp cutoff value. Rather, the ability of an analysis to detect asbestos (i.e., observe one or more structures) spans a relatively wide range (about two orders of magnitude) of concentration values, with a high probability of detection at the high end and a low probability of detection at the low end.

5. The range of concentrations that can be detected in an analysis of a filter is not fixed, but depends on the number of GOs evaluated. The greater the number of GOs evaluated, the greater the ability of the analysis to detect the presence of asbestos. In concept, nearly any analytical sensitivity may be achieved by counting a large enough number of GOs.

6. Human health risk from inhalation exposure to asbestos is related to the long-term average exposure concentration in air, so it is necessary to base risk evaluations on the average of multiple air samples that are representative of exposure levels over time and space. The best-estimate of the long-term average for a specified scenario is equal to the average of the samples that represent that scenario, treating non-detects as zero. If a non-zero surrogate value (e.g., ½ S or S) is assigned to non-detects, the resulting estimate of the mean will tend to be biased high, but may provide a helpful indication of uncertainty, especially for data sets with a high fraction of non-detects.

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TABLE 1
90% POISSON CONFIDENCE BOUNDS ON COUNTS

N_{obs}	ISO 10312 (ISO 1995)		Box and Tiao (1973)	
	0.05 LB	0.95 UB	0.05 LB	0.95 UB
0	[0]	2.996	0.002	1.921
1	0.051	4.744	0.176	3.907
2	0.355	6.296	0.573	5.535
3	0.818	7.754	1.084	7.034
4	1.366	9.154	1.663	8.459
5	1.970	10.513	2.287	9.838
6	2.613	11.842	2.946	11.181
7	3.285	13.148	3.630	12.498
8	3.981	14.435	4.336	13.794
9	4.695	15.705	5.059	15.072
10	5.425	16.962	5.796	16.335
11	6.169	18.208	6.545	17.586
12	6.924	19.443	7.306	18.826
13	7.690	20.669	8.076	20.057
14	8.464	21.886	8.854	21.278
15	9.246	23.097	9.640	22.493
16	10.036	24.301	10.433	23.700
17	10.832	25.499	11.233	24.901
18	11.634	26.692	12.037	26.096
19	12.442	27.879	12.848	27.286
20	13.255	29.062	13.663	28.471
25	17.382	34.916	17.800	34.335
30	21.594	40.691	22.019	40.116
40	30.196	52.069	30.631	51.505
50	38.965	63.287	39.407	62.729

LB = lower bound count
N_{obs} = number of structures observed
UB = upper bound count

TABLE 2
VALUE OF x0 FOR VARIOUS VALUES OF λ_0

Expected Count from Background (λ_0)	Decision value (x0)
0.00 – 0.05	0
0.05 – 0.35	1
0.35 – 0.81	2
0.81 – 1.36	3
1.36 – 1.97	4
1.97 – 2.61	5

Notes:
x0 = the highest count than could reasonably arise from background

Source: ASTM 6620-06

FIGURE 1
UNCERTAINTY AS A FUNCTION OF COUNT

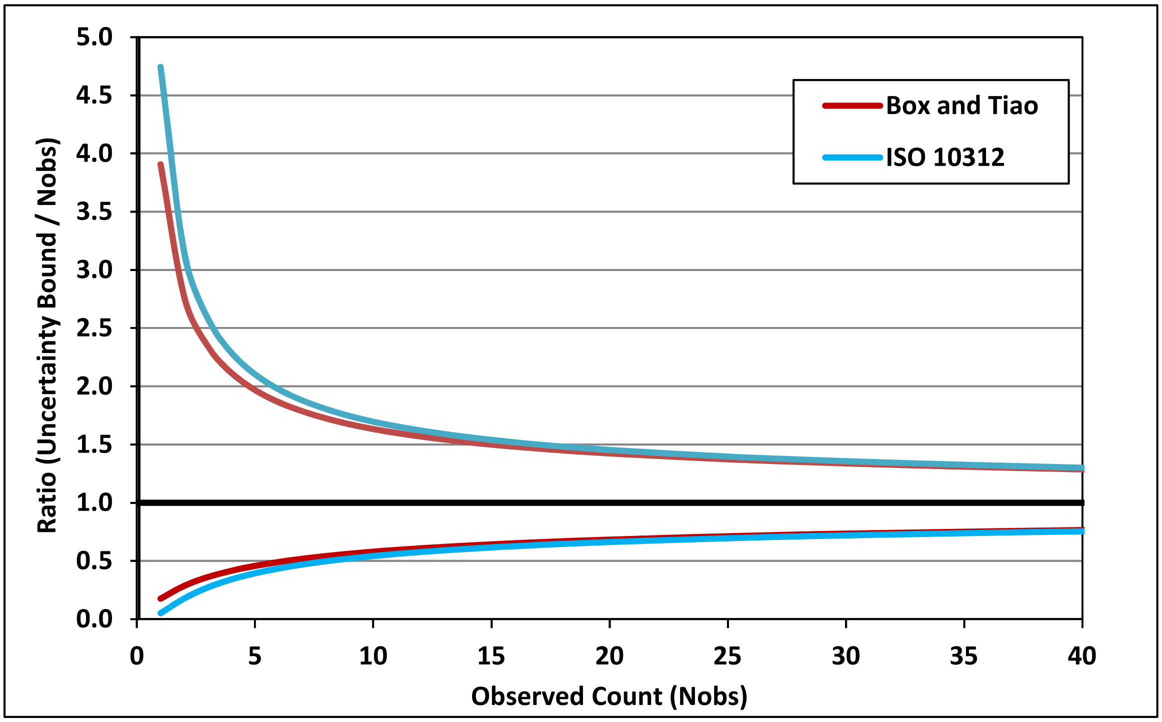


FIGURE 2
PROBABILITY OF DETECTION AS A FUNCTION OF CONCENTRATION

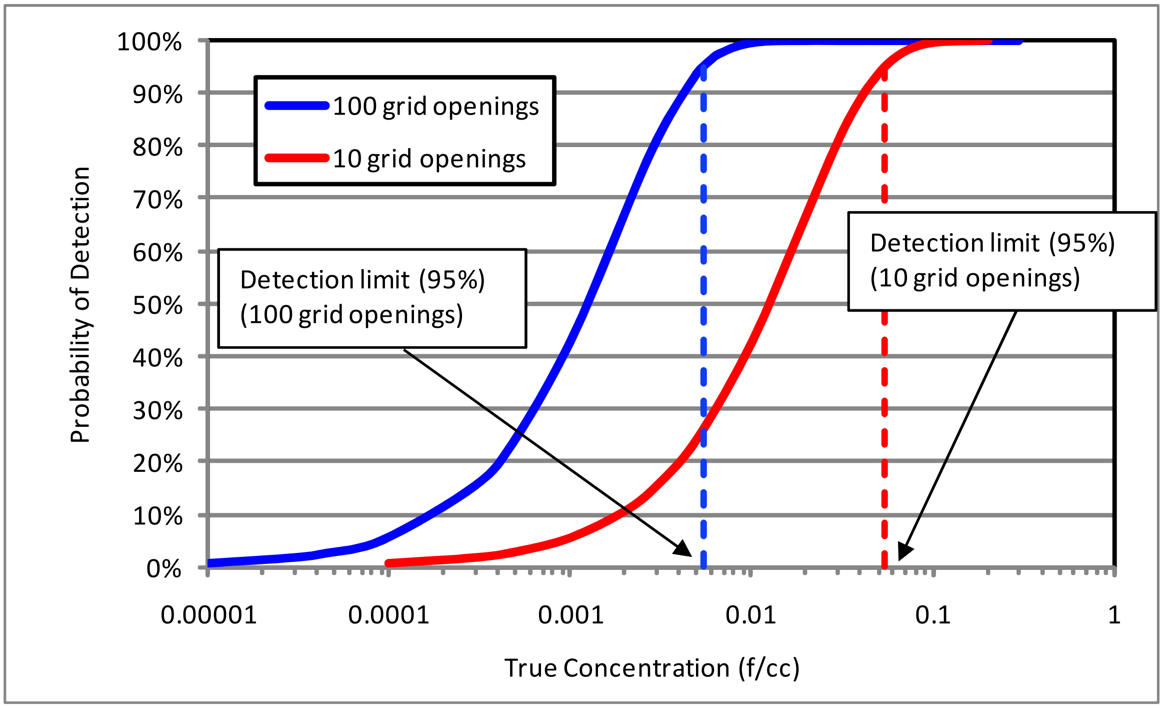
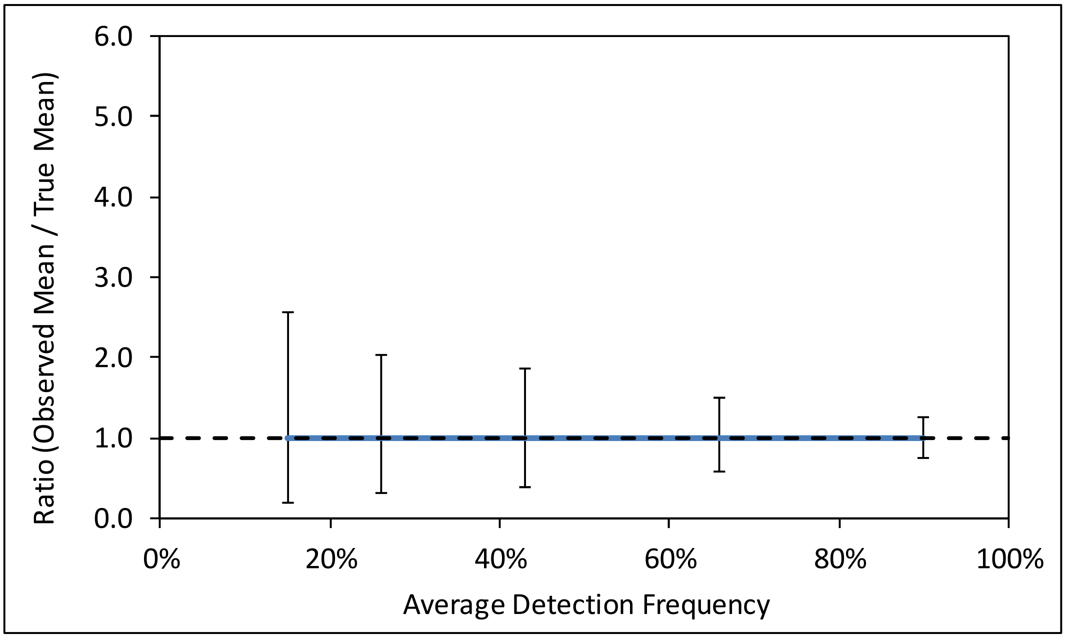
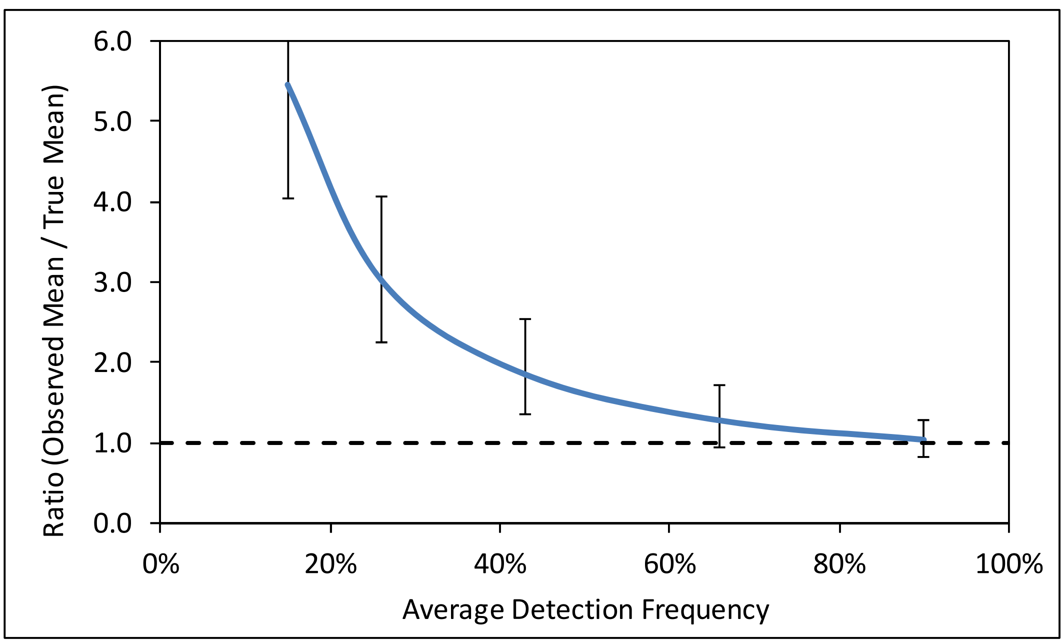


FIGURE 3
BIAS INTRODUCED BY USING SURROGATE VALUES FOR NON-DETECTS

Panel A: Non-Detects Evaluated as Zero



Panel B: Non-Detects Evaluated at 1/2*S



APPENDIX C

DEFINITION OF PHASE CONTRAST MICROSCOPY-EQUIVALENT (PCME)

The Libby amphibole asbestos (LA)-specific toxicity factors were derived by fitting mathematical models to data that characterize the relationship between exposure to LA in workplace air and the occurrence of cancer or non-cancer effects in exposed workers. The studies that were used reported measures of asbestos concentration in workplace air that were obtained by phase contrast microscopy (PCM). Consequently, it is mandatory that risk estimates based on these toxicity factors be calculated using measures of concentration that are expressed in comparable units.

While analysis by PCM remains an option, the U.S. Environmental Protection Agency (EPA 2008) generally recommends that asbestos analyses at Superfund sites be performed using transmission electron microscopy (TEM). This is mainly because PCM cannot reliably distinguish between asbestos and non-asbestos fibers, while TEM can distinguish asbestos from non-asbestos and can also distinguish between asbestos mineral types. Consequently, when measures of concentration have been obtained by TEM, it is necessary to specify rules that allow identification of PCM-equivalent (PCME) structures that were observed in the TEM analysis.

The counting rules most likely followed by PCM microscopists at the time the workplace studies of LA exposure (1950s-1980s) were performed defined a fiber[1] as any visible structure with a length longer than 5 micrometers (µm) and an aspect ratio (length divided by width) of 3:1 or greater (National Institute for Occupational Safety and Health [NIOSH] 1977). No specific mention is made of any width resolution limit in NIOSH (1977). Based on a review of historical literature, it appears that the lower limit of width resolution by PCM varied between studies, depending upon the visual acuity of the analyst, optical performance of the microscope, and optical properties (refractive index) of the asbestos structures.

- Rendell and Skikne (1980) performed a study for the National Centre for Occupational Health in Johannesburg, South Africa in which known fibers, as determined by electron microscopy, were examined by PCM. They reported that 100 percent (%) of amosite fibers with a width greater than (>) 0.5 µm were visible by PCM, whereas 30% of fibers with a width of 0.2-0.4 µm and only 3% of fibers with a width less than (<) 0.2 µm were visible. Based on these results, the authors adopted a PCM limit of resolution of 0.4 µm.
- LeGuen *et al.* (1980) evaluated the effect of refractive index on fiber visibility and established a lower width detection limit of 0.2-0.25 µm for chrysotile, while Hwang and Gibbs (1981) estimated a lower limit of 0.21 µm for crocidolite.
- Rooker *et al.* (1982) performed a study of various fibrous materials, including several types of asbestos and man-made mineral fibers, to determine the variability and limits of fiber resolution under a range of analysis conditions. They found that "fibers of diameter 0.15 µm should be visible with good optics".
- Taylor *et al.* (1984) describes a study in which amosite and wollastonite fiber concentrations obtained by PCM and electron microscopy were compared for filters prepared using a fluidized

[1] In a PCM analysis, any particle (asbestos or non-asbestos) meeting the dimensional criteria is referred to as a "fiber". In a TEM analysis, particles are designated based on specific structure types (e.g., fibers, bundles, clusters). For simplicity, this document uses the term "structure" to refer to both PCM fibers and TEM PCME structures.

bed generator. According to the authors, "[t]he resolution limit of the phase contrast microscope was estimated to be 0.25 µm by observing reference slides…of known diameter".

- The World Health Organization identifies a lower width boundary of 0.25 µm for PCM, stating that "mineral fibres down to about 0.25 µm in diameter (lower for amphiboles than for chrysotile) are visible and countable" (International Programme on Chemical Safety [IPCS] 1986).

Based on these reports, it is concluded that the lower width boundary of detection by PCM likely varied from about 0.15 µm to 0.4 µm, depending upon the study, with the majority of studies supporting a value of about 0.25 µm. The lower width boundary of 0.25 µm is supported by the current NIOSH Method 7400 for PCM (NIOSH 1994), which states that "[f]ibers < ca. 0.25 µm diameter will not be detected by this method".

A related issue is whether there should be an upper bound on the thickness of PCME structures. Walton (1982) provides a comprehensive review of the PCM counting rules that have been applied historically, and notes that an upper width boundary of 3 µm for PCM counting was adopted internationally in 1971 based on findings by Timbrell *et al.* (1970) that amphibole fibers found in lung tissue had a maximum diameter of 3 µm. However, Walton (1982) indicates that the U.S. did not adopt this limit, and specifically states that the PCM methods used in the U.S. do not specify an upper diameter limit. Indeed, a review of the historical and current NIOSH methods for PCM (NIOSH 1977; 1994) shows that no upper diameter limit is imposed.

Based on this information, when estimating exposure point concentrations for air samples analyzed by TEM for use in the risk characterization, PCME structures are defined as follows:

- Length > 5 µm
- Width ≥ 0.25 µm (no upper limit)
- Aspect ratio ≥ 3:1

It is acknowledged that the width criterion that is used in the risk assessment differs from what is specified in EPA's *Framework for Investigating Asbestos-Contaminated Superfund Sites* (EPA 2008), which specifies an upper width limit of 3 µm. As illustrated in **Figure 2-3** (main text), very few (<1%) LA structures observed on air filters have a width > 3 µm.

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APPENDIX D

DATA QUALITY ASSESSMENT

The purpose of this appendix is threefold:

1) To describe the quality assurance (QA) procedures and quality control (QC) measures that have been established to govern the collection and analysis of environmental samples at the Libby Asbestos Superfund Site (Site);
2) To summarize the results for a variety of different types of QA/QC evaluations and analyses across the various sampling programs; and
3) To draw conclusions about the accuracy, precision, and reliability of reported results, and their suitability for use in risk assessment.

The *QA/QA Summary Report for 1999-2009* (CDM Federal Programs Corporation [CDM Smith] 2012) and the *QA/QA Summary Report for 2010-2013* (CDM Smith 2014), along with the *Annual QA/QC Summary Report* (2007-2012) for Operable Unit 3 (OU3) (CB&I Federal Services, LLC [CB&I] 2013a), provide detailed discussions of QA/QC for the Site. In addition, information pertaining to laboratory audits and data validation has been summarized in *Annual QA/QC Summary Report* (2010-2012) (CB&I 2013b). Information on specific QA/QC activities conducted for each investigation is provided in the investigation-specific data summary reports.

A program-wide overview of QA activities for the field, soil preparation laboratory, and analytical laboratories is discussed below in Section D.1, Section D.2, and Section D.3, respectively. Section D.4 summarizes QC results, Section D.5 summarizes data management QA procedures and Section D.6 summarizes other data quality metrics that were evaluated to ensure results used in the risk assessment were of high quality.

D.1 Field Quality Assurance Activities

D.1.1 General

Field QA activities include processes and procedures to ensure that field samples are collected, handled, and documented properly, and that any issues/deficiencies associated with field data collection or sample processing are quickly identified and rectified. Detailed information on field QA activities can be found in the investigation-specific sampling and analysis plans (SAPs) and/or quality assurance project plans (QAPPs). These SAP/QAPPs were developed in general accordance with the U.S. Environmental Protection Agency (EPA) *Requirements for Quality Assurance Project Plans, EPA QA/R-5* (EPA 2001) and the *Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G4* (EPA 2006).

With the exception of Operable Unit 7 (OU7; Troy, Montana) and OU3 (the former mine site), activity-based sampling (ABS) and ambient air sampling programs at the Site were conducted by EPA contactors (e.g., CDM Smith, Tech Law, Inc. [Tech Law]). Because the Montana Department of Environmental Quality (DEQ) is the lead agency for OU7, investigations were conducted by the DEQ's contractor, Tetra Tech EM Inc. (Tetra Tech). For OU3, there is an Administrative Order on Consent between EPA and W.R. Grace and Company (Grace); therefore, sampling programs were conducted by Grace contractors in accordance with EPA-developed SAP/QAPPs.

The SAP/QAPPs were implemented by field contractors that were trained in asbestos sampling methodology. The following bullets summarize the components of the field QA program implemented at the Site:

- **Field Team Roles/Responsibilities** – There were a variety of field personnel involved in the sampling investigations conducted at the Site and each individual had assigned roles and responsibilities. The field team leader (FTL) oversaw all sample collection activities to ensure that governing documents were implemented appropriately. The field QA manager was responsible for ensuring that all field efforts were conducted in accordance with the governing SAP/QAPP and applicable QA requirements.

- **Field Team Training** – Individuals involved in the collection, packaging, and shipment of samples completed appropriate training, including Occupational Safety and Health Administration (OSHA) 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) and relevant 8-hour refresher updates, respiratory protection, and asbestos awareness training.

- **Orientation –** Field personnel were required to attend an orientation session with the field Health and Safety (H&S) manager, as well as an orientation session on sample collection techniques.

- **Investigation-Specific Documentation –** Field personnel were required to review and understand all applicable governing documents associated with the sampling investigation, including the SAP/QAPP, all associated standard operating procedures (SOPs), and the applicable Health and Safety Plan (HASP).

- **Readiness Reviews –** Meetings were conducted prior to beginning field sampling activities to discuss and clarify the objectives, equipment and training needs, field SOPs, QC samples, and H&S requirements for each investigation.

- **Field Documentation Review** – Field documentation was completed by field staff using Site-specific field forms. These field forms provided a standardized method of documenting sample information generated in the field. Field documentation was reviewed by the FTL on a regular basis to ensure the accuracy of the recorded sample information.

- **Equipment Maintenance/Calibration** – All field equipment was maintained in accordance with manufacturer specifications and Site-specific SOPs. For air samples, each air sampling pump was calibrated to the desired flow rate using a primary calibration standard prior to sample collection.

- **Equipment Decontamination** – Reusable equipment used in sample collection was decontaminated in accordance with Site-specific SOPs. Any disposable equipment or other investigation-derived waste (IDW) was handled in conformance with SOP requirements.

- **Sample Custody/Tracking** – All samples collected at the Site were tracked and managed in accordance with Site-specific SOPs for sample custody and tracking, using appropriate chain of custody (COC) forms.

- **Field QC Samples** – A variety of different types of field QC samples were collected as part of the investigations conducted at the Site. These QC samples provide information on potential

contamination arising from sample collection methods, as well as information on result precision. (See Section D.4.1 for a detailed discussion of field QC results.)

- **Modification Documentation** – Major deviations from the SAP/QAPP that modified the sampling approach or associated guidance documents were recorded on a field record of modification (ROM) form. These ROMs were reviewed and approved by EPA.

D.1.2 Field Oversight

An important component of the field QA program is field oversight, which includes both field surveillances and field audits depending on the complexity of the investigation.

Field surveillances consist of periodic observations made to evaluate continued adherence to investigation-specific governing documents. Investigation-specific field surveillances were performed by the field contractor QA manager (or their designee). If not explicitly stated in contract requirements or the SAP/QAPP, the schedule for performing field surveillances was determined based on the duration of the investigation, frequency of execution, and magnitude of process changes. Typically, field surveillances were performed during the first week of a new field program to identify and mitigate issues early on, provide continuous improvement of processes and procedures, and facilitate mentoring/training. Thereafter, surveillances were conducted once a month or as necessary when field processes were revised or other QA/QC procedures indicated the possibility of deficiencies.

Field audits are broader in scope than field surveillances. Audits are evaluations conducted by qualified technical or QA staff that are independent of the activities audited. All aspects of data and sample collection, as well as sample documentation, handling, custody, and shipping are evaluated as part of a field audit. Field audits were conducted by field contractors, internal EPA staff, or EPA-contracted auditors in accordance with contract requirements or the investigation-specific SAP/QAPP. Like surveillances, field audits were typically conducted during the early stages of an investigation to identify and mitigate issues early on and provide for continuous improvement. Typically, at least one field audit was conducted for investigations with a project duration of one year.

There were numerous field surveillances and audits performed for the ABS and ambient air sampling programs. Detailed findings for each field surveillance/audit are documented in separate investigation-specific reports and are summarized in the *QA/QC Summary Reports* (CDM Smith 2012, 2014). The majority of the observations noted in the surveillances and audits pertained to adherence to field documentation processes (e.g., a visitor was not documented in the logbook); however, occasionally, deficiencies were noted (e.g., soil moisture was not measured). To the extent possible, observations and deficiencies were addressed at the time they were discovered and in all cases, impacts were evaluated and improvements made to prevent recurrence. The impacts were determined to be minimal, such that they did not or were not likely to have negative impacts on Site data. This suggests that the field surveillance and auditing program has been effective in improving field data quality and compliance.

Information on audits and surveillances for OU7 was not available at the time of this report.

D.2 Soil Preparation Laboratory Quality Assurance Activities

D.2.1 General

Soil or soil-like samples collected at the Site were sent to a soil preparation facility for drying, sieving, and grinding prior to analysis by the Site-specific polarized light microscopy (PLM) methods. From 2003 until about 2009, with the exception of OU7[1], all soil samples were prepared at the Close Support Facility (CSF) in Denver, Colorado, which was staffed by CDM Smith employees. Beginning in about 2009, all soil samples were sent to the Sample Preparation Facility (SPF) in Troy, Montana for preparation. The SPF is staffed by Tech Law employees.

The *CSF Soil Preparation Plan* (CDM Smith 2004) served as the guidance document for all activities at the CSF. The *SPF Soil Sample Preparation Work Plan* (Tech Law 2007) served as the guidance document for all activities at the SPF. The purpose of these soil preparation plans (SPPs) is to provide standard guidance on preparation methods to ensure that these procedures and resulting measurements were scientifically sound and of acceptable and documented quality. The following bullets summarize components of the QA procedures at the soil preparation laboratories:

- **Personnel Training** – Individuals involved in the processing of samples were required to have read and understood the SPP, all associated SOPs, as well as the facility HASP. In addition, personnel completed appropriate training, including OSHA 40-hour HAZWOPER and relevant 8-hour refresher updates.

- **Documentation Review** – Sample preparation documentation was completed by preparation laboratory staff using Site-specific forms. These forms provided a standardized method of documenting sample preparation information. This documentation was reviewed on a regular basis to ensure the accuracy of the recorded preparation information.

- **Equipment Maintenance/Calibration** – All weight scales, ventilation hoods, and drying ovens used in sample preparation were maintained and calibrated in accordance with manufacturer specifications. In addition, the plate grinder was calibrated daily to verify proper particle size and demonstrate that samples were not over-processed.

- **Equipment Decontamination** – Sample preparation equipment was decontaminated between each sample in accordance with the Site-specific sample preparation SOP.

- **Facility Contamination Monitoring –** The preparation laboratory performed regular contamination monitoring to evaluate worker safety, ensure laboratory cleanliness, and assess the potential for cross-contamination of samples submitted to the facility.

- **Sample Custody/Tracking** – All samples processed at the preparation laboratory were tracked and managed in accordance with COC requirements specified in the SPPs.

- **Preparation QC Samples** – A variety of different types of preparation QC samples were included in the preparation of samples collected as part of the investigations conducted at the

[1] All soil samples collected from OU7 (Troy) were prepared at the SPF (even those collected prior to 2009).

Site. These QC samples provide information on potential cross-contamination arising from sample preparation methods as well as information on result precision. See Section D.4.2 for a detailed discussion of preparation QC results.

- **Modification Documentation** – Major deviations from the SPPs were recorded on a ROM form. These ROMs were reviewed and approved by EPA.

D.2.2 Audits

EPA's Quality Assurance Technical Support (QATS) contractor (CB&I, formerly Shaw Environmental, Inc. [Shaw]) performed an audit of the CSF in Denver on October 2, 2008 and three audits of the SPF in Troy on September 18, 2008, August 7, 2012, and July 11, 2013. Specific activities that were audited included the general laboratory facility, laboratory organization and personnel, general housekeeping, sample receipt and storage, sample preparation procedures, measurements and documentation, sample shipping procedures, and QA/QC procedures.

The 2008 CSF audit report was issued in March of 2009 (Shaw 2009). In brief, a total of 17 observed deficiencies were noted during the 2008 CSF audit. The majority of the observed deficiencies occurred within the following laboratory process area categories: sample preparation procedures (bulk drying), sample receipt, and QA/QC procedures (CB&I 2013b).

For the Troy SPF, a total of eight deficiencies were identified in 2008 and 10 deficiencies were identified in 2012. The laboratory process area categories in which the majority of the observed deficiencies occurred included preparation procedures (bulk drying, grinding, and splitting) and QA/QC procedures (CB&I 2013b). A follow-up audit of the Troy SPF was performed in 2013 (CB&I 2013c) to evaluate corrective actions taken by the laboratory to address deficiencies identified during the 2012 audit. The audit revealed that the laboratory had only completely addressed five, partially addressed one, and failed to address four of the ten deficiencies noted in the 2012 audit. The partially-addressed deficiency was identified for sample receipt and tracking (a final, complete, and signature-approved SOP for sample receiving, login, tracking, shipping, and archiving of samples was not available at the time). The deficiencies that were not addressed included a failure to calibrate and certify the balance on an annual basis by an outside vendor, a failure to accurately determine grinding recoveries, and a failure to weigh the dried portion, the fine fraction, and the coarse fraction to the nearest 0.1 gram of the sample. Corrective actions were recommended and were evaluated during the next audit in August of 2014. This audit revealed that all previously identified deficiencies were addressed (CB&I 2014). However, during this audit, two new deficiencies were noted in preparation procedures (the entire sample was not being homogenized and processed) and QA/QC procedures (grinding blanks were the first samples processed during the grinding process) (CB&I 2014). Since the 2014 audit, processing procedures have been modified to address each of these deficiencies. This suggests that the on-site audit program has been effective in improving preparation laboratory quality and compliance.

D.3 Analytical Laboratory Quality Assurance Activities

D.3.1 General

All laboratories selected for analysis of samples for asbestos were part of the Libby analytical laboratory team. These laboratories had demonstrated experience and expertise in analysis of Libby amphibole

asbestos (LA) in environmental media, and all were part of an ongoing Site-specific QA program designed to ensure accuracy and consistency of reported analytical results between laboratories. These laboratories were audited by EPA's QATS contractor and the National Institute of Standards and Technology (NIST)/National Voluntary Laboratory Accreditation Program (NVLAP) on a regular basis.

Laboratory QA activities include all processes and procedures designed to ensure that data generated by an analytical laboratory are of high quality and that any problems in sample preparation or analysis that may occur are quickly identified and rectified. The following bullets summarize the laboratory QA procedures that were required of each laboratory that analyzed samples from the Site.

- **Laboratory QA Management Plan** – Each laboratory developed a laboratory-specific *QA Management Plan* that provided a detailed description of the procedures and policies in place at their laboratory to ensure laboratory quality.

- **Certifications** – All analytical laboratories were subject to national, local, and project-specific certifications and requirements. Each laboratory was accredited by the NIST/NVLAP for the analysis of airborne asbestos by transmission electron microscopy (TEM) and/or analysis of bulk asbestos by polarized light microscopy (PLM). This included the analysis of NIST/NVLAP standard reference materials, or other verified quantitative standards, and successful participation in two proficiency rounds per year each of bulk asbestos by PLM and airborne asbestos by TEM supplied by NIST/NVLAP.

- **Team Training/Mentoring Program** – Laboratories were required to participate in a training/mentoring program to ensure they can demonstrate the ability to perform reliable analyses at the Site. The training process included a review of morphological, optical, chemical, and electron diffraction characteristics of LA using Site-specific reference materials, as well as training on Site-specific analytical methodology, documentation, and administrative procedures.

- **Technical Discussions/Conferences** – Laboratories participated in regular technical discussions with EPA and their contractors, as well as attended professional/technical conferences. These discussions enabled the laboratory and technical team members to have an ongoing exchange of information regarding all analytical and technical aspects of the project.

- **Analyst Training** – All TEM and PLM analysts were required to undergo method-specific training and understand the application of standard laboratory procedures and methodologies, including the Libby-specific analytical methods. Analysts familiarized themselves with the Site-specific method deviations, project-specific documents, and visual references.

- **Data Reporting** – Standardized benchsheets and data entry spreadsheets were developed specifically for the Site to ensure consistency between laboratories in the presentation and submittal of analytical data. All analysts were trained in the Site-specific reporting requirements and data reporting tools utilized in transmitting results.

- **Laboratory QC Samples** – A variety of different types of laboratory QC analyses were collected as part of the investigations conducted at the Site. These QC analyses provide information on potential contamination arising from laboratory preparation and analysis methods as well as

information on result accuracy and precision. (See Section D.4.3 for a detailed discussion of analytical laboratory QC results.)

- **Laboratory Contamination Monitoring** – Each analytical laboratory performed regular contamination monitoring to evaluate worker safety and ensure laboratory cleanliness in compliance with their SOPs and certification requirements.

- **Modification Documentation** – Changes or revisions needed to improve or document specifics about analytical methods or laboratory procedures were documented using a laboratory ROM form. These ROMs were reviewed and approved by EPA.

D.3.2 Laboratory Audits

Each laboratory conducted internal audits of their specific operations on an annual basis using appropriate checklists in accordance with their laboratory-specific *QA Management Plan*. As noted above, the laboratories that were part of the Libby analytical laboratory team were also audited by EPA's QATS contractor on a regular basis to specifically evaluate adherence to all Libby-specific analytical requirements. On-site audits were used by EPA to verify that samples analyzed by their contract facilities were being processed in accordance with EPA requirements. Each on-site audit included a review of the general elements of preparation, on-site support, and report generation, which were modified as needed to fit the type of audit being performed.

The first series of laboratory audits was conducted in January of 2001. Because of performance concerns noted during this audit, one of the analytical laboratories was released from the Libby laboratory program. This laboratory did not analyze any of the ambient air or ABS air samples used in the risk assessment.

Nearly all of the air sample results that form the basis of the exposure assessment used in the risk characterization were analyzed from 2006 to 2013. A comprehensive series of laboratory audits was conducted in April-September 2008 to evaluate the TEM and PLM laboratories that support the Site. A second round of analytical laboratory audits was performed in June-August 2012. A third round of analytical laboratory audits was performed in May-October 2013. Detailed findings for each laboratory audit are documented in separate laboratory-specific audit reports. The overall conclusions of the 2008 and 2012 laboratory audits are presented in CB&I (2013b) and summarized below.

A total of 93 observed deficiencies, compiled from the completed summary on-site audit reports, were identified for six different analytical laboratories in 2008. The deficiencies identified in these laboratory audits were grouped into eight laboratory process areas. The laboratory process categories in which the majority of the observed deficiencies occurred included PLM, sample preparation, sample receiving, and QC/QA; whereas the laboratory process categories with the least frequently occurring deficiencies included TEM, facility, and data management. EPA requires that laboratories provide responses to on-site audit reports that include the laboratory's proposed corrective action to each of the identified audit deficiencies. Laboratory responses to the 2008 on-site audit reports were received from all the Libby team laboratories. The laboratory responses provided proposed corrective actions for the identified findings along with objective evidence as applicable. No findings were contested.

A total of 66 deficiencies were identified in the 2012 audits across eight analytical laboratories. An average number of 9.4 deficiencies per laboratory in 2012 represents a 39.4 percent (%) decrease from the 15.5 average number of deficiencies per on-site audit (for the same six laboratories) recorded in 2008. All six laboratories audited in 2008 and again in 2012 showed a significant reduction in the number of defects, which indicates that all six laboratories applied appropriate corrective actions in response to their initial audits in 2008. This suggests that the on-site audit program has been effective in improving analytical laboratory quality and compliance.

All of the analytical laboratories evaluated in 2012 were re-evaluated in 2013 to determine if the deficiencies identified in 2012 had been adequately addressed. Although a comprehensive report summarizing the findings of the 2013 audits is currently in preparation, but the individual laboratory audit reports are available and have been reviewed. In general, most of the deficiencies identified in 2012 were addressed. Also, the overall number of deficiencies per laboratory in 2013 was less than identified in 2012. Again, this suggests that the on-site audit program has been effective in improving analytical laboratory quality and compliance.

D.4 Quality Control Results

As discussed above, a variety of field QC samples, preparation laboratory QC samples, and analytical laboratory QC analyses were included as part of the sampling investigations performed at the Site. A detailed review and discussion of the results for all QC samples and analyses is provided in the 1999-2009 and 2010-2013 *Quality Assurance and Quality Control Reports* (CDM Smith 2012, 2014). The following sub-sections summarize the overall conclusions from these reports.

D.4.1 Field Quality Control Samples

Various types of field-based QC samples have been collected for air and soil samples as part of investigations conducted at the Site. The investigation-specific SAP/QAPPs specified the field QC sample types and collection/analysis frequency required for each investigation. A detailed review of field QC sample results is provided in CDM Smith (2012, 2014) and summarized briefly below.

<u>Lot Blanks</u>

A lot blank is an air filter cassette that has been taken from a new, unused box of filter cassettes. Lot blanks were collected to ensure that filters in unused cassettes do not have any asbestos contamination prior to their use in the field. Lot blanks were prepared by submitting unused cassettes for analysis prior to putting the cassette lot into use and were reviewed by designated field staff responsible for the project sample cassette inventory. Over 800 lot blank analyses were performed (typically, 10 grid openings are examined for each lot blank analysis). No asbestos structures were observed on any lot blank samples; therefore, it is concluded that the cassette lots were asbestos-free and usable for air sample collection at the Site.

<u>Field Blanks</u>

Field blanks were collected to evaluate potential contamination introduced during air sample collection, shipping and handling, or analysis. Air field blanks were collected by removing the end cap of the sample cassette to expose the filter in the same area where sample collection occurred for approximately 30

seconds before re-capping the sample cassette. The field blanks were analyzed for asbestos by the same method used for field sample analysis.

If asbestos was observed on the analyzed field blank, all other field blanks collected by that team during that week were submitted for analysis to determine the potential impact on the related sample results. If any asbestos was observed on a field blank, the FTL and/or laboratory manager was notified and appropriate measures taken (e.g., retraining) to ensure staff are employing proper sample handling and analysis techniques. In addition, a qualifier of "FB" is added to the related field sample results in the project database (see Section D.5.1) to denote that the associated field blank had asbestos structures detected.

More than 7,600 field blank samples have been collected and analyzed by TEM as part of the various air sampling programs at the Site. Typically, 10 grid openings are examined for each field blank analysis. Approximately 0.1% of these field blanks contained LA structures, with no field blank samples containing LA structures since 2002. On average, the total asbestos background filter loading rate across all field blanks was about 0.01 fibers per square millimeter (f/mm^2). When asbestos fibers were detected, in many cases, TEM results were also available for an additional field blank sample that was collected by the same field team at the same property on the same day as the field blank containing LA structures, and this additional field blank did not indicate detectable levels of LA. This suggests that contamination of air samples due to field sampling methods occurs rarely, and when detections are noted, they do not appear to be associated with systemic or large-scale field sampling issues. Based on the low frequency of detectable LA structures observed in field blanks, it is concluded that contamination of collected air samples due to field sampling methods is not a significant issue and impacts on reported LA air concentrations are negligible.

Field Duplicates/Splits

Field duplicates were collected from the same sampling location at the same time as the parent field sample. Field duplicates were collected using the same collection technique as the parent sample. Field duplicates were analyzed by the same method as field samples and were blind to the analytical laboratories (i.e., the laboratory could not distinguish between field samples and field duplicates).

Field duplicates were not routinely collected for air, but were collected as part of several investigations. In order to be ranked as concordant, air field duplicate results must not be statistically different from the "parent" field sample at the 90% confidence interval (CI), as evaluated using the Poisson ratio test[2] (Nelson 1982). More than 200 air field duplicates have been collected, with almost 99% being ranked as concordant. These results show that air field duplicate results are reproducible and reliable.

For soil, field duplicates analyzed by PLM-VE were considered concordant if the reported PLM-VE "bin" result for the field duplicate was the same as the original sample. Results were ranked as "weakly discordant" if the field duplicate was within one bin of the parent field sample. Results were ranked as "strongly discordant" if the field duplicate was different by two bins. There are no concordance requirements established for soil field duplicates. Rather, concordance results are used to inform data users on result variability.

[2] Laboratory ROM LB-000029 includes an Excel spreadsheet tool that can be used by the laboratory staff to make this statistical comparison.

Results are available for approximately 1,700 soil field duplicates. The overall percentages on agreement are as follows:

- Concordant = 85%
- Weakly discordant = 15%
- Strongly discordant = 0.5%

When field duplicate results differed from the parent field sample, it was usually due to differences between Bin A (non-detect) and Bin B1 (trace; detected at levels less than 0.2% by mass). While field duplicate discordances may occur due to authentic field spatial heterogeneity, preparation variability and/or analytical uncertainty, the soil field duplicate results support the conclusion that estimates of soil concentration by PLM-VE were generally reproducible and reliable.

D.4.2 Preparation Laboratory Quality Control Samples

The preparation laboratory QC samples were collected to ensure that the preparation techniques utilized to process soil samples did not introduce potential contamination and to evaluate variability associated with preparation techniques. Two types of preparation laboratory QC samples were collected by the soil preparation facilities – preparation blanks (including grinding blanks and drying blanks) and preparation duplicates. A detailed review of the preparation laboratory QC sample results is provided in CDM Smith (2012, 2014) and summarized briefly below.

<u>Preparation Blanks</u>

A drying blank consists of approximately 100 to 200 grams of asbestos-free quartz sand that is processed with each batch of field samples that were dried together (usually there were approximately 125 samples per batch). Drying blanks are processed identically to field samples and determine if cross-contamination between samples is occurring during sample drying. More than 2,200 drying blanks have been analyzed and 99% have been reported as non-detect (Bin A) by PLM-VE. On the rare occasion that LA was detected in a drying blank, results were reported as trace (Bin B1).

A grinding blank consists of asbestos-free quartz sand that is processed along with the field samples on days that field samples are ground. Grinding blanks determine if decontamination procedures of laboratory soil processing equipment used for sample grinding and splitting were adequate to prevent cross-contamination. Grinding blanks are prepared at a frequency of one per grinding batch per grinder per day. More than 2,000 grinding blanks have been analyzed and 99% have been reported as non-detect (Bin A) by PLM-VE. When LA was detected, results were reported as trace (Bin B1).

These results indicate that inadvertent contamination during soil sample drying and grinding processes occurred rarely and is not expected to impact reported LA soil concentrations by PLM-VE.

<u>Preparation Duplicates</u>

Preparation duplicates are splits of field samples submitted for sample preparation. Preparation duplicates are used to evaluate the variability that arises during the soil preparation and analysis steps. After drying, but prior to sieving, a preparation duplicate is prepared by using a riffle splitter to divide

the field sample (after an archive split has been created) into two approximately equal portions, creating a parent and duplicate sample. The variability between the preparation duplicate and the associated field sample reflects the combined variation due to sample preparation (sieving and grinding) and to PLM measurement error.

More than 2,800 preparation duplicates have been analyzed by PLM-VE. Preparation duplicate results were evaluated using the same methods as described above for field duplicates. Overall concordance results are as follows:

- Concordant = 87%
- Weakly discordant = 13%
- Strongly discordant = 0.2%

Preparation duplicate results are considered acceptable if the frequency of weak discordances is less than 20% and the frequency of strong discordances is less than 5%. As shown, the preparation duplicate results meet these acceptance criteria.

When preparation duplicate results differed from the parent sample, it was usually due to differences between PLM-VE Bin A (non-detect) and Bin B1 (trace). Slight differences between aliquots of the same sample are expected due the inherent heterogeneity of soil samples and the limitations of the PLM-VE method at the low levels observed at the Site. The results for preparation duplicates are generally similar to the results for field duplicates (see Section D.4.1). These results support the conclusion that the soil sample results are generally reproducible and reliable and were not greatly influenced by differences in soil preparation and analysis techniques.

D.4.3 Analytical Laboratory Quality Control Analyses

In the risk assessment, two types of air samples formed the basis of the exposure assessment – ABS air and ambient air. All ABS and ambient air samples were analyzed for asbestos using TEM. Soil samples were analyzed by the Site-specific PLM methods. Laboratory QC analyses and results for TEM and PLM are summarized briefly below.

D.4.3.1 TEM

The laboratory QC requirements for TEM analyses at the Site were patterned after the requirements set forth by NVLAP, and include:

- Laboratory blanks
- Repreparations
- Recounts (i.e., recount same, recount different, and verified analyses)
- Inter-laboratory analyses

A detailed review of the results for each type of TEM laboratory QC analysis is provided in CDM Smith (2012, 2014) and summarized briefly below.

Laboratory blanks

A laboratory blank is an analysis of TEM grids that are prepared from a new, unused filter which has been prepared and analyzed using same procedures as used for field samples. Laboratory blanks monitor overall laboratory cleanliness. More than 2,400 laboratory blank samples have been analyzed by TEM. Typically, 10 grid openings are examined for each laboratory blank analysis. No LA structures have been observed in any laboratory blank sample. Based on these results, it is concluded that the TEM preparation and examination procedures within the analytical laboratories have not introduced LA contamination.

Repreparations

A repreparation is an analysis of TEM grids that are prepared from a new section of the same field filter used to prepare the original grids. Typically, this is done within the same laboratory that performed the original analysis, but a different laboratory may also prepare grids from a new piece of the filter. If the repreparation is performed within the same laboratory, the repreparation and reanalysis is performed by a different analyst than performed the original analysis, whenever possible.

Repreparation analyses were evaluated by the analytical laboratory by comparing the results for the original and the repreparation analyses. In order to be ranked as concordant, the results must not be statistically different from each other at the 90% CI, as evaluated using the Poisson ratio test[3] (Nelson 1982). If the repreparation results were found to be statistically different from the original analysis results, a senior analyst investigated to see if this discordance was related to laboratory procedures, and took appropriate corrective action as needed (e.g., re-training in sample and filter preparation, counting rules, quantification of size, identification of types, etc.).

More than 800 repreparation analyses of air samples have been performed by the TEM laboratories. Repreparation analyses for air samples were statistically different at the 90% CI for approximately 5% of these analyses. This observed frequency (5%) is within the expected frequency (10%) based on random variation. Even when results were statistically different, LA air concentrations for repreparations were usually within a factor of 10 of the originally reported air concentration. These results indicate that TEM air concentrations have good precision and are not greatly influenced by differences in grid preparation techniques.

Recount Analyses

Recount analyses are a re-examination (or recount) of the original TEM grid openings that were evaluated in the initial analysis. This may be done in several different ways, as follows:

- ***Recount Same* –** This is an analysis in which the original TEM grid openings are re-examined by the same microscopist who performed the initial examination.

[3] Laboratory ROM LB-000029 includes an Excel spreadsheet tool that can be used by the laboratory staff to make this statistical comparison.

- ***Recount Different* –** This is an analysis in which the original TEM grid openings are re-examined by a different microscopist in the same laboratory than who performed the initial examination.

- ***Verified Analysis* –** This analysis is similar to a Recount Different but has more detailed requirements with regard to documentation. A verified analysis must be recorded in accordance with the protocol provided in NIST (1994).

- ***Inter-laboratory* –** This is an analysis in which a previously analyzed sample is re-prepared by the original laboratory and these TEM grid openings are re-examined by a microscopist in a different laboratory than the initial examination. Inter-laboratory analyses are selected post hoc by the QATS contractor or their designee. The list of samples selected for inter-laboratory analysis is provided to the LC, who coordinates with the analytical laboratories to ensure that selected samples are prepared and analyzed in accordance with the inter-laboratory procedures in laboratory ROM LB-000029.

Recount analysis results were evaluated based on grid opening- and structure-specific concordance criteria presented in laboratory ROM LB-000029. Results of the TEM laboratory QC analyses show that there have been some differences in structure counting and recording methods within and between the analytical laboratories, with within-laboratory precision being better than between-laboratory precision (CDM Smith 2012; 2014, CB&I 2013a). For example, concordance rates for the number of LA structures per grid opening were approximately 99% for recount same, recount different, and verified analyses (based on approximately 27,000 grid opening pairs), whereas concordance rates were 75% for inter-laboratory analyses (based on approximately 1,100 grid opening pairs).

Concordance rates for matched structures were about 99% for mineral class, 84-99% for structure length, and 88-100% for structure width for within-laboratory recounts; whereas between-laboratory concordance rates for matched structures were about 87-98% for mineral class, 84-93% for structure length, and 98-99% for structure width. These concordance rates primarily are in the “acceptable” to “good” range based on program-wide criteria specified in laboratory ROM LB-000029. Based on these results, the between-laboratory differences in structure counting and recording methods are not expected to be a large source of uncertainty in reported air concentrations.

D.4.3.2 PLM

Three types of laboratory-based QC analyses were performed for PLM-VE, including laboratory duplicates (both self-checks and cross-checks), inter-laboratory analyses, and performance evaluation (PE) standard analyses.

Laboratory Duplicates

A laboratory duplicate *self-check* is a repreparation of a soil sample slide by the same analyst. A laboratory duplicate *cross-check* is a reanalysis of a soil sample slide by a different analyst. More than 6,000 laboratory duplicate analyses have been performed. Laboratory duplicate results were evaluated using the same methods as described above for field duplicates.

Overall concordance was generally good for both laboratory duplicate self-check and cross-check analyses, with more than 97% of laboratory duplicate results ranked as concordant. When results were different between the original sample and the laboratory duplicate, they were usually only weakly discordant (i.e., results were within one bin). These results show that there was good within-laboratory reproducibility in PLM-VE LA results.

Inter-Laboratory Analyses

An inter-laboratory analysis is an examination of a second fine ground aliquot of the same soil sample by a PLM analyst at a different laboratory than completed the original analysis. Inter-laboratory results are evaluated using the same concordance evaluation methods as described above for laboratory duplicates.

To date, more than 400 PLM-VE inter-laboratory analyses have been performed. The overall concordance rate for inter-laboratory analyses tends to be lower than for laboratory duplicate analyses, with rates ranging from 51 to 94% (depending upon the time period). These inter-laboratory results show that there are differences between the analytical laboratories in reported LA PLM-VE bin results, mainly in the distinction between non-detect (Bin A) and trace (Bin B1) LA soil concentrations (CB&I 2012; CDM Smith 2012; 2014). In particular, EPA's Environmental Services Assistance Team, Region 8 (ESATR8) laboratory has demonstrated proficiency in detecting the presence of trace levels (Bin B1) of LA in soil compared to other laboratories (CDM Smith 2014) (i.e., the ESATR8 laboratory is able to detect trace LA in soil samples ranked as non-detect [Bin A] by other PLM laboratories).

In general, the majority of soil samples used to group the outdoor ABS air data were analyzed by the ESATR8 laboratory. Thus, there is less uncertainty in the PLM-VE results for the soil samples used in the risk assessment. However, the ESATR8 laboratory did not begin performing PLM-VE analyses until about 2008; thus, soil samples collected prior to this would have been analyzed by non-ESATR8 laboratories. Any extrapolation of the risk characterization results to properties and locations without outdoor ABS that is based on soil data must consider which PLM laboratory performed the soil analyses. Even for PLM analyses performed by the ESATR8 laboratory, all soil sample results have uncertainty due to the inherent variability in the analytical method.

Performance Evaluation Standard Analyses

The U.S. Geological Survey has prepared several different Site-specific reference materials for use during PLM-VE analyses (EPA 2008b). These reference materials were prepared by adding known aliquots of LA spiking material to uncontaminated[4] soils from Libby to obtain several different nominal LA concentrations (based on mass percent). Aliquots of these reference materials are utilized as performance evaluation (PE) standards to evaluate PLM-VE laboratory accuracy and precision. PE standard results are ranked as acceptable if the correct semi-quantitative bin is reported, as determined by the nominal concentration of the PE standard.

Over 160 PE standards, representing a range of nominal levels, have been analyzed by the PLM laboratories. In general, about 70% were ranked as concordant (meaning the reported bin was the same

[4] Recent analyses of "non-detect" PE standards, which were prepared using the unspiked soil (the uncontaminated Libby soils), have been shown to contain LA fibers when analyzed by TEM following preparation by fluidized bed. In all cases, the "non-detect" PE standards have been ranked as Bin A by PLM-VE. These results highlight the fact that PLM-VE is not able to reliably detect low levels (less than 0.05%) of LA in soil.

as the expected bin based on the nominal level). When results were discordant, they were usually only weakly discordant (i.e., within one bin) and tended to be biased low. Less than 5% of PE standards had results that were ranked as strongly discordant. PE standards with nominal LA levels near bin boundaries (i.e., 0.2%, 1%) were the most difficult to assign accurately. These results demonstrate that PLM-VE results are generally accurate but there are inherent uncertainties associated with reported binned results.

D.5 Data Management Quality Assurance Activities

D.5.1 Database

<u>Application</u>

Historically, there was a single standard query language (SQL) server database for the entire Libby project, referred to as the "Libby2 Database", which was used to manage and maintain most[5] sample information, analysis details, and analytical results for all samples collected at the Site. The Libby2 Database was also used to track property status information. As of December 2009, the Libby2 Database was decommissioned and archived on EPA's server at the Region 8 office in Denver, CO.

Beginning in January 2010, field and analytical Site data has been managed in Scribe. Scribe is a software tool developed by EPA's Environmental Response Team (ERT) to assist in the process of managing environmental data. A Scribe project is a Microsoft® Access database. Multiple Scribe projects can be stored and shared through Scribe.NET, which is a web-based portal that allows multiple data users controlled access to Scribe projects. Local Scribe projects are "published" to Scribe.NET by the entity responsible for managing the local Scribe project. External data users "subscribe" to the published Scribe projects *via* Scribe.NET to access data. Subscription requests have been managed by ERT.

All field-related data (e.g., sample information, location specifics, pump information) contained in the Libby2 Database, which included all investigative and H&S programs conducted at the Site from 1999-2009, have been migrated to Scribe. However, the analytical information and results have not and will not be migrated to Scribe. These data can be accessed in the historical Libby2 Database which is available upon request from EPA.

Due to the nature of asbestos analysis and other data reporting requirements, the project databases were developed iteratively, expanding in capabilities (and complexity) as project-specific needs evolved. In addition to providing new functionality, as needed, enhancements were made to accommodate data user needs and to incorporate various automated QA/QC procedures to improve data integrity.

Because data are continually being generated as a result of ongoing sampling and analysis at the Site, the project databases are dynamic. Each day, new sample, analysis, and results records are added and records are corrected, as appropriate. As a result, any database-generated queries, tables, figures, maps, and reports provide only a "snapshot" of the database on the day the output was created. All data summaries included in the risk assessment are based on a database snapshot dated October 31, 2014.

[5] Investigation samples from OU3 and OU7 were not maintained in the Libby2 Database. OU3 data is managed in an OU3-specific Microsoft Access® relational database and OU7 data has always been managed in OU7-specific Scribe projects.

Administration and Security

As noted above, Scribe subscription requests are managed by ERT. A data user cannot gain access to the Scribe databases without being provided subscription information, which includes a login and password specific to each Scribe project.

Data Entry Processes

The project databases have a variety of built-in QC functions that improve accuracy of data entry and help maintain data integrity. For example, field data entry forms utilize drop-down menus whenever possible. Drop-down menus allow the data entry personnel to select from a set of standard inputs. The use of drop-down menus prevents duplication and transcription errors and limits the number of available selections (e.g., valid media types).

The analytical laboratories were required to transmit results using Site-specific electronic data deliverable (EDD) spreadsheets. Each EDD contains a variety of built-in QC functions that improve the accuracy of data entry and help maintain data integrity. For example, data entry forms utilize drop-down menus whenever possible to standardize data inputs and prevent transcription errors. In addition, many data input cells are electronically checked in the EDD spreadsheet to highlight omissions, apparent inconsistencies, or unexpected values so that data entry personnel can check and correct any errors before submittal of the EDD. These spreadsheets also perform automatic computations of analytical sensitivity, dilution factors, and concentration, thus reducing the likelihood of analyst calculation errors.

The transmitted EDDs were uploaded directly into the project databases using "upload" procedures designed specifically for each type of EDD, which avoids potential errors related to manual entry of the results. Each upload procedure performed several integrity checks to ensure that records were consistent and complete prior to uploading the analytical data. For example, the project database allows a unique sample ID to only be entered once, thus ensuring that different samples cannot inadvertently be assigned the same sample number. If issues were identified, the analytical EDD was not uploaded until the issues were rectified.

D.5.2 Asbestos Data Verification

Prior to the preparation of any data summary reports, a cursory data review was performed on applicable data to identify potential omissions, unexpected values, or apparent inconsistencies. Because analytical laboratories utilized Site-specific EDD spreadsheets, data checking of reported analytical results began with automatic QC checks built into these spreadsheets (discussed above). In addition to these automated checks, as dictated by the governing investigation-specific SAP/QAPP, a more thorough data verification evaluation was also performed to ensure the consistency and quality of reported data.

Asbestos data verification included checking that results are transferred correctly from the original hand-written, hard copy field and analytical laboratory documentation to the project database. This data verification process utilized Libby-specific SOPs developed to ensure TEM and PLM results and field sample information in the database were accurate and reliable. The SOP for TEM verification (SOP EPA-LIBBY-09) and PLM verification (SOP EPA-LIBBY-10) describe the review of the laboratory benchsheets and verification of the transfer of results from the benchsheets into the project database. The SOP for field sample data sheet (FSDS) verification (SOP EPA-LIBBY-11) describes the steps for the verification

of field sample information, based on a review of the FSDS form, and verification of the transfer of results from the FSDS forms into the project database. An FSDS review is performed on all samples selected for TEM or PLM data verification.

The goal of the data verification was to identify and correct data reporting errors. The frequency of data verification was specified in each investigation-specific SAP/QAPP; typically, a minimum of 10% of sample and analysis results were verified. This frequency increased if there were issues identified in the verification effort. For the purposes of the Libby residential sampling efforts, 100% of sample and analysis results were verified prior to the distribution of results to the property owner. For Troy, 20% of the sample and analysis results were verified[6].

In brief, most of the issues identified during these data verification efforts were non-critical in nature, meaning that they were typographical errors and inconsistencies that did not influence LA results or data interpretation. The frequency of critical errors (i.e., those that could influence LA results and data interpretation) was generally low. Error frequencies tended to be higher following particular programmatic changes in laboratory methods and data reporting requirements and at the beginning of sampling investigations.

All issues identified during the various data verification efforts were submitted to the field teams and/or analytical laboratories for resolution and rectification. All tables, figures, and appendices generated for this risk assessment reflect corrected data.

D.5.3 Asbestos Data Validation

Unlike asbestos data verification, where the goal was to identify and correct data reporting errors, the goal of asbestos data validation was to evaluate overall data quality and to assign data qualifiers, as appropriate, to alert data users to any potential data quality issues.

Until recently, formal data validation guidelines for asbestos did not exist. Thus, data validation efforts were performed by EPA technical contractors following the completion of each investigation and consisted primarily of a review and assessment of field and laboratory ROM forms, field QC data (e.g., field duplicates, field blanks), and laboratory QC data (e.g., recounts, repreparations) to identify potential data quality issues with respect to result precision, accuracy, representativeness, completeness, and comparability. No review of instrument calibration or control standard data was performed, as this type of information was included in the regular NVLAP certification process.

In late 2011, EPA released a draft of the *National Functional Guidelines (NFGs) for Asbestos Data Review* (EPA 2011b). These guidelines include review criteria and recommended data qualifiers for validation of TEM and PLM data. However, these draft asbestos NFGs have not been finalized. Consequently, EPA's QATS contractor (CB&I) developed Libby-specific SOPs for data validation of asbestos datasets based on the draft asbestos NFGs. In 2013, CB&I performed a formal data validation of asbestos results for investigations conducted from 2007 to 2012. A detailed summary of this data validation effort is summarized in CB&I (2013b). The conclusions of this review are summarized below.

[6] It should be noted that there were issues identified in the Troy residential sampling effort where additional verification may be desirable to support risk management decision-making.

More than 2,200 field samples from over 250 different laboratory jobs analyzed by five different laboratories between 2007 and 2012 were selected for validation. Samples for validation were selected randomly (5% frequency), choosing samples that were representative across laboratory, analysis method, and media. Less than 0.5% of the selected analyses required qualification. No ambient air samples were qualified and only six ABS air samples were qualified (two were R-qualified and four were J-qualified). When qualification was needed, it was usually due to the failure of the laboratory to perform and/or document daily calibration activities. No R-qualified analyses were used in the HHRA.

Based on the very low frequency of qualification, the data validation results support the conclusion that the reported air and soil concentrations used in the risk assessment are of high quality.

D.6 Other Data Quality Evaluation Metrics

Three additional data quality evaluation metrics were evaluated for air samples analyzed by TEM to ensure reported LA concentrations were of adequate quality and reliable to support risk management decision-making. This included the confirmation of the TEM analysis stopping rules (Section D6.1), a test of filter loading evenness (Section D6.2), and an assessment of the frequency and effect of indirect filter preparation methods (Section D6.3). Each are these metrics are discussed further below.

D.6.1 Confirmation of TEM Analysis Stopping Rules

Specific requirements for the TEM analysis of air samples are detailed in the governing SAP/QAPPs. These requirements include the TEM analysis stopping rules. In general, three alternative stopping rules are specified for TEM analyses to ensure resulting data are adequate:

1. The target analytical sensitivity (TAS) to be achieved
2. A maximum number of LA structures to be counted
3. A maximum area of filter to be examined

When one of these stopping rules is met, the TEM analyst can stop counting grid openings and the analysis is complete.

Target Analytical Sensitivity (TAS). As discussed in **Appendix B**, there is no “preset” lower limit of analytical sensitivity for TEM; in theory, the analytical sensitivity can be lowered simply by reading more and more grid openings. The level of analytical sensitivity needed to ensure that the analysis of an air sample will be adequate for use in risk assessment is derived by finding the concentration of LA in air that might be of potential concern, and then ensuring that if an air sample were encountered that had a true concentration equal to that level of concern, it would be quantified with reasonable accuracy. Thus, the TAS was determined for each investigation based on a back-calculated risk-based concentration (RBC) that was specific to the receptor and exposure scenario for each investigation to ensure the resulting achieved analytical sensitivities would be adequate to support Site-specific risk estimates and decision-making.

In general, most TEM analyses for ambient and ABS air samples used in the risk assessment achieved the TAS; however, for several of the earlier (pre-2011) ABS datasets, the specified TAS at the time was not adequate to support decisions based on the non-cancer endpoint. This is because earlier ABS programs were conducted prior to the development of the draft LA-specific reference concentration (RfC) and

RBCs were derived to be protective of the cancer endpoint, which is not the most sensitive endpoint (see Section 4.2 in the main text). EPA has performed several supplemental[7] TEM analyses on datasets to achieve an improved sensitivity for specific ABS datasets, including a subset of 2010 Operable Unit 4 (OU4) ABS air samples during soil disturbances in yards, gardens, and driveways, a subset of the recreational and occupational ABS air investigations in forested areas surrounding OU3, and a subset of the OU4 outdoor schools ABS air samples.

Maximum Number of LA Structures. For filters that have high asbestos loading, reliable estimates of concentration may be achieved before achieving the TAS. This is because the uncertainty around a TEM estimate of asbestos concentration in a sample is a function of the number of structures observed during the analysis (see **Appendix B**). The goal was to specify a maximum number of structures such that the resulting Poisson uncertainty was not a substantial factor in the evaluation of method precision. For most investigations, the maximum number of LA structures was 25 structures (meaning that the analysis could stop if 25 structures were recorded regardless of the achieved sensitivity). As shown in **Figure 10-1** (see the main text), above about 25 structures, there is little change in the relative uncertainty due to Poisson uncertainty.

Few air samples utilized in the risk assessment achieved the maximum number of LA structures stopping rule; typically, most samples have lower structure counts (fewer than 10 structures). Because of this, and because there is no EPA-approved method for calculating upper confidence limits (see **Appendix B**), it is important to recognize that the exposure estimates used in the risk assessment are uncertain due Poisson counting error (analytical uncertainty) as well as sampling variability.

Maximum Filter Area to be Examined. The number of grid openings that must be examined during a TEM analysis of an air sample depends upon the TAS, the air sample volume, and – if an indirect preparation was necessary – the dilution needed during the indirect preparation (i.e., f-factor). Depending upon these inputs, the number of grid openings that would need to be examined to achieve the TAS may become excessive. The maximum filter area is specified to limit the analytical time and cost spent on any single analysis. For investigations conducted prior to 2010, the maximum filter area was usually about 0.5 mm^2 to 1 mm^2 (about 50-100 grid openings). For investigations conducted after 2010 (after the draft LA-specific RfC value was developed which showed that much lower analytical sensitivities were necessary to support risk estimates), the maximum filter area was usually about 10 mm^2 to 20 mm^2 (about 1,000-2,000 grid openings).

Analyses that were stopped due to the maximum filter area examined stopping rule have the largest uncertainty relative to the other stopping rules described above. As discussed in the Uncertainty Assessment (Section 10.1.2 of the main text), for most datasets, the fact that the TAS was not achieved will not alter overall risk assessment conclusions; however, supplemental TEM analysis could be performed for some of the earlier (pre-2011) datasets to reduce uncertainties.

D.6.2 Evenness of Air Filter Loading

An analysis of an air filter by TEM assumes that the filter is evenly loaded (i.e., that fibers are distributed at random across the filter). The assessment of filter loading evenness is evaluated using a Chi-square

[7] A supplemental analysis is where the TEM analyst examines additional grid openings for the same filter (and often the same grids) as the original analysis. Results of the supplemental analysis are pooled with the original analysis using the equation shown in Section 2.3.2 of the main text.

(CHISQ) test, as described in ISO 10312 Annex F2. If a filter fails the CHISQ test for evenness, the reported result may not be representative of the true concentration in the sample, and the results should be given low confidence.

An evaluation of filter loading was typically performed for each investigation and summarized in the investigation-specific data summary reports. In general, the majority of ambient and ABS air samples passed the CHISQ test (i.e., p value ≥ 0.001). For example, out of 220 filters analyzed from the 2011 OU4 outdoor residential ABS investigation, 214 (97%) passed the CHISQ test. During the 2007/2008 outdoor residential investigation, 449 out of 460 filters (98%) passed the CHISQ test. Because of the low frequency of CHISQ failures, it is concluded that uneven filter loading is not of significant concern and is not likely a source of uncertainty for air samples used in the risk assessment.

D.6.3 Indirect Preparation of Air Filters

As discussed in Section 2.3.4 and 10.1.3 of the main text, if an air filter was deemed to be overloaded or if loose material was noted in the air cassette or adhering to the cowl, the filter was prepared indirectly (usually with ashing) in accordance with the indirect filter preparation procedures in Libby-specific SOP EPA-LIBBY-08. For chrysotile asbestos, indirect preparation tends to increase structure counts due to dispersion of bundles and clusters; however, the effects of indirect preparation on amphibole asbestos are generally much smaller, usually only increasing concentrations by a factor of 2-3 (Berry *et al.* 2014; Goldade and O'Brien 2014).

As seen in **Table D-1**, the frequency of indirect preparation varies by investigation. Ambient air samples were prepared indirectly at a frequency of 2% (across all OUs and sampling programs), while ABS air filter tended to have a higher frequency of indirect preparation, depending on the ABS investigation. As expected, most of the filters that required indirect preparation were collected during source disturbance scenarios where dust generation was higher. For example, 64% of yard ABS air samples collected under the "high intensity" ABS script in 2007/2008 required indirect preparation. For OU3, more than half of the ABS air samples collected while cutting fire lines in the forested area required indirect preparation.

In order to ensure that air concentrations used in the risk assessment were not biased high due to filter preparation methods, concentrations for all air samples that were indirectly prepared were adjusted (decreased) by a factor of 2.5. This factor was based on Libby-specific studies of the potential effect of indirect preparation on air samples (Berry *et al.* 2014). However, the actual effect of indirect preparation likely depends upon the nature of the LA structures present on the filter, which could differ depending upon the source material (e.g., soil, tree bark, VI), the sampling location (e.g., at the mine site in OU3, inside an attic at an OU4 residence), and the type of disturbance activity. Hence, an estimated concentration calculated using an adjustment factor of 2.5 may be higher or lower than the true concentration.

D.7 Data Quality Assessment Summary and Conclusions

Investigations at the Site have generated a large amount of data on the LA concentration in air and soil, which were used in the risk assessment to quantify potential human exposures and risks. EPA developed and implemented an extensive a QA/QC program for the Site to ensure that the quality of the data collected could be evaluated to ensure they were adequate to support management decisions on potential risks to human health from exposures to LA.

Key elements of the QA plan included:

- The development of detailed SAP/QAPPs to guide all sample collection and analysis efforts
- The development of detailed Site-specific SOPs for sample collection, preparation, and analysis
- Extensive training of all field and laboratory staff
- Extensive review and checking by senior staff of the work performed by field and laboratory staff
- Periodic internal and external audits of field and laboratory operations
- Iterative modifications to improve methods and document procedures used to address any issues or problems identified by field staff, laboratory staff, or data users
- The development of electronic data management tools for recording and transferring data that include a variety of error checks
- The collection and analysis of a variety of different types of QC samples
- Validation and verification of electronic data in the project databases

Based on the QC data that have been collected at the Site, it is concluded that:

- Blank samples (e.g., lot blanks, field blanks, preparation blanks, laboratory blanks) show that inadvertent contamination of field samples with LA or other forms of asbestos is not of significant concern, in the field, at the soil preparation facility, or at the analytical laboratory.

- Field duplicate samples show that variability due to small-scale heterogeneity and sample analysis is likely to be small and results tend to be reproducible.

- Soil preparation duplicates show that results are not greatly influenced by differences in soil preparation techniques.

- For both TEM (air) and PLM (soil), there is generally high agreement (good concordance) for intra-laboratory analyses. Inter-laboratory analyses suggest that, while results are generally acceptable, there are some differences in methods or procedures between analytical laboratories.

  - For TEM, between-laboratory differences in structure counting and recording methods are not expected to be a large source of uncertainty in reported air concentrations.

  - For PLM, there are differences between the analytical laboratories in reported LA PLM-VE bin results, mainly in the distinction between non-detect (Bin A) and trace (Bin B1) LA soil concentrations. However, there is less uncertainty in the PLM-VE results used in the risk assessment because the majority of soil samples used to group the outdoor ABS air data were analyzed by the ESATR8 laboratory (a laboratory with demonstrated proficiency in detecting the presence of trace levels of LA in soil).

Taken together, these results indicate the QA/QC procedures used at the Site have been effective in ensuring that the data collected are of high quality. As such, these data are considered representative, of acceptable quality, and reliable and appropriate to support risk management decision-making.

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TABLE D-1
Summary of Indirect Preparation Frequency by Investigation
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU1	Summer 2013	Post-Construction ABS	Collection of personal ABS air samples during mowing and weed-trimming activities at the park	9	0	0%
OU2	Summer 2012	Post-Construction ABS	Collection of personal ABS air samples during mowing along the Flyway right-of-way and while hiking along the Kootenai River	9	0	0%
OU3	Summer 2009	Phase III	Collection of personal ABS air samples during recreational activities in the forest (ATV-riding, hiking, campfire building/burning)	227	0	0%
	Summer 2010 - 2011	Phase IV-A	Collection of personal ABS air samples while hiking along Rainy Creek	10	7	70%
			Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually and with heavy equipment)	60	36	60%
	Summer 2012	Phase V-A	Collection of personal ABS air samples during recreational activities in the Kootenai River	2	0	0%
	Summer 2014	Pulaski Nature and Extent	Collection of personal ABS air samples during USFS firefighter activities in the forest (cutting firelines manually)	60	0	0%
OU4	Summer 2001	Phase 2, Scenario 4	Collection of personal ABS air samples during garden rototilling	2	0	0%
	Summer 2007, Spring 2008	2007-2008 OU4 Residential Outdoor ABS	Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	450	287	64%
	Summer 2009	Libby Schools Outdoor ABS	Collection of personal ABS air samples while playing outside at schools	30	12	40%
			Collection of personal ABS air samples while mowing lawns at schools	15	5	33%
			Collection of personal ABS air samples while performing maintenance activities at schools (power-sweeping, digging, raking, and sweeping)	18	7	39%
	Summer 2010	2010 OU4 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	120	3	3%
			Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	60	5	8%
			Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	62	2	3%
			Scenario 5: Collection of personal ABS air samples while bicycling on paths/trails in Libby	90	0	0%
	Summer 2011	2011 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards (using 2 different ABS scripts)	80	31	39%
			Scenario 2: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards previously evaluated in 2010	31	0	0%
			Scenario 3: Collection of personal ABS air samples during mowing in residential yards pre- and post-irrigation	18	2	11%
			Scenario 4: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards where curb-to-curb removal has been completed	31	5	16%
			LUA: Collection of personal ABS air samples during ATV riding in limited-use areas at residential properties	60	31	52%

TABLE D-1
Summary of Indirect Preparation Frequency by Investigation
Libby Asbestos Superfund Site

Panel A: Outdoor ABS Studies During Soil/Duff Disturbances (cont.)

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU5	Summer/Fall 2008	Worker ABS	Collection of personal ABS air samples during outdoor worker activities (bulldozer operator, raking)	48	37	77%
		MotoX ABS	Collection of personal and stationary ABS air samples during activities at the MotoX track	34	3	9%
		Recreational ABS	Collection of personal ABS air samples while bicycling on bike path in OU5	46	17	37%
OU6	Summer 2008	BNSF ABS	Collection of personal and stationary ABS air samples during rail maintenance activities	46	4	9%
OU7	Spring/Summer 2011	OU7 Residential Outdoor ABS	Scenario 1: Collection of personal ABS air samples during raking, mowing, digging activities in residential yards	41	1	2%
			Scenario 2: Collection of personal ABS air samples during digging activities in residential gardens	38	2	5%
			Scenario 3: Collection of personal ABS air samples during playing, digging activities on residential driveways	40	2	5%
			Scenario 4: Collection of personal ABS air samples while bicycling on paths/trails in Troy	40	0	0%
OU8	Spring 2011, Summer 2010	OU8 Outdoor Worker ABS	Collection of equipment and stationary ABS air samples during road rotomilling activities	61	5	8%
			Collection of equipment ABS air samples during mowing and brush-hogging activities	14	2	14%
	Summer 2010	2010 OU4 Residential Outdoor ABS, Scenario 5	Collection of personal ABS air while driving on roads in Libby	20	0	0%
	Summer 2011	OU7 Residential Outdoor ABS	Collection of personal ABS air while driving on roads in Troy	20	0	0%

Panel B: ABS Studies During Disturbances of Wood-Related Materials

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU3	Summer 2010	2010 OU3 Phase IVA ABS	Collection of ABS air samples while performing activities as part of the USFS land management responsibilities, including maintenance of roads and trails, thinning of trees and vegetation, and surveying trees (i.e., stand examination).	90	30	33%
			Collection of personal ABS air during residential wood harvesting at three locations in the forested area downwind (northeast) of the mine site (i.e., approximately 2 miles, 4 miles, and 8 miles from the mine site)	62	46	74%
	Summer 2012	2012 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, “hooking and skidding” felled trees to a central landing area, mechanical de-limbing and cutting of timber, and site restoration of the landing area using a bulldozer	13	6	46%
	Summer 2013	2013 Souse Gulch Wildfire Contingency Monitoring Plan Air	Collection of air samples to provide measured data on LA exposures of responding firefighters (both to the ground crews and the aircraft support pilot) and downwind LA concentrations in air during the fire.	18	0	0%
	Summer 2014	2014 OU3 Commercial Logging ABS	Collection of personal ABS air during hand-felling of trees, “hooking and skidding” felled trees to a central landing area, mechanical processing, milling, cutting slabs pre-milling, and site restoration of the landing area using a bulldozer	29	2	7%
OU4	Summer 2011	2011 OU4 Miscellaneous ABS	Collection of ABS air samples from each of the two piles in OU5	15	0	0%
	Summer 2012	2012 OU4 ABS Woodstove Ash	Collection of air samples to measure LA concentrations in air during woodstove ash-removal activities	9	9	100%
OU5	Fall 2007	Former Stimson Lumber Mill Site-Wood Chip Pilot Study	Collection of personal ABS air samples for the excavator operator and sampling personnel during the waste bark and wood chip pile test pit excavations	16	0	0%
OU7	Spring 2013	2013 Troy Landfill Activity-Based Sampling	Collection of ABS air samples during woodchipping of a woodwaste pile at the Lincoln County Landfill in Troy	6	0	0%

TABLE D-1
Summary of Indirect Preparation Frequency by Investigation
Libby Asbestos Superfund Site

Panel C: Indoor ABS Studies

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU1	Winter 2012	Clearance Sampling	Search and Rescue builidng clearance samples	5	5	100%
OU4	Summer 2001	Phase 2	Scenario 1 & 2: Collection of personal ABS air during active and passive residential/commercial behaviors	59	12	20%
			Scenario 3: Collection of personal ABS air during simulated tradesperson activities	17	3	18%
	Summer 2005	SQAPP, Task 2	Collection of personal ABS air samples during passive (no active) residential behaviors	29	8	28%
	Summer 2007 - Spring 2008	2007-2008 OU4 Residential Indoor ABS	Collection of personal ABS air samples during active and passive residential behaviors	641	212	33%
	Summer 2009	Libby Schools Indoor ABS	Collection of stationary ABS air samples inside schools	50	2	4%
	Various	Tradesperson Re-Analysis	Re-analysis of collected personal H&S samples of workers during interior removal activities (bulk removal, demolition, detailing attic, and wet wipe/HEPA vacuum)	17	3	18%
	Winter 2013, Summer 2013	2013 OU4 Residential Indoor ABS	Scenario 1: Collection of personal ABS air samples during active and passive residential behaviors at properties where a curb-to-curb soil removal has been completed	40	1	3%
	Summer 2013		Scenario 2: Collection of personal ABS air samples during active and passive residential behaviors at properties evaluated in 2007/08	20	1	5%
OU5	Winter 2007	Indoor Worker ABS	Collection of personal ABS air samples during active and passive worker behaviors inside occupied OU5 buildings	37	23	62%
			Collection of stationary ABS air samples inside vacant OU5 buildings	50	47	94%
OU7	Spring, Summer 2011	OU7 Residential/Commercial Indoor ABS	Collection of personal ABS air samples during active and passive residential and commercial behaviors	80	6	8%

Panel D: Ambient Air Studies

Operable Unit	Sampling Date	Investigation	Description	Number of Air Samples	Number Samples Prepped Indirectly	Indirect Preparation Freq. (%)
OU2	2007-2008	Ambient Air	Collection of ambient air samples throughout OU2	34	0	0%
OU3	2007-2008	Ambient Air	Collection of ambient air samples throughout OU3	96	0	0%
OU4	2006-2013	Ambient Air	Collection of ambient air samples throughout OU4	803	21	3%
OU6	2007-2008	Ambient Air	Collection of ambient air samples throughout OU6	35	0	0%
OU7	2009-2013	Ambient Air	Collection of ambient air samples throughout OU7	612	10	2%

Notes:
ABS - activity-based sampling
BNSF - Burlington Northern and Santa Fe
H&S - health and safety
HEPA - high efficiency particulate air
LA - Libby amphibole asbestos
OU - operable unit
SQAPP - Supplemental Remedial Investigative Quality Assessment and Project Plan
USFS - United States Forest Service

APPENDIX E

DETAILED DATA SUMMARY FOR ALL SAMPLES USED IN THE HUMAN HEALTH RISK ASSESSMENT

[provided electronically in attached Excel file]

APPENDIX F

ESTIMATED RISKS FROM EXPOSURES TO LA DURING DISTURBANCES OF SOILS IN OU3 - STRATIFIED BY ABS AREA

APPENIDIX F

Estimated Risks from Exposures to LA During Disturbances of Soils in OU3 - Stratified by ABS Area

Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Location*	ABS Area	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)$^{+}$	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Recreational Visitor	Hiking	Along Rainy Creek	RC	0.0093	6	48	50	0.023	**4E-05**	**2**
		Forest, near	ABS-10	0	8	50	50	0.033	**0E+00**	**0**
			ABS-14	0.0010	8	50	50	0.033	**6E-06**	**0.4**
		Forest, intermed.	ABS-03	0.00086	8	50	50	0.033	**5E-06**	**0.3**
			ABS-05	0.00075	8	50	50	0.033	**4E-06**	**0.3**
			ABS-06	0	8	50	50	0.033	**0E+00**	**0**
			ABS-07	0.0015	8	50	50	0.033	**8E-06**	**0.5**
			ABS-13	0	8	50	50	0.033	**0E+00**	**0**
		Forest, far	ABS-01	0	8	50	50	0.033	**0E+00**	**0**
			ABS-02	0	8	50	50	0.033	**0E+00**	**0**
			ABS-08	0	8	50	50	0.033	**0E+00**	**0**
			ABS-11	0.0010	8	50	50	0.033	**6E-06**	**0.4**
		Across all forest areas		0.00048	8	50	50	0.033	**3E-06**	**0.2**
	ATV-riding	Forest, near	ABS-10	0.0030	4	50	50	0.016	**8E-06**	**0.5**
			ABS-14	0	4	50	50	0.016	**0E+00**	**0**
		Forest, intermed.	ABS-03	0.0017	4	50	50	0.016	**5E-06**	**0.3**
			ABS-05	0	4	50	50	0.016	**0E+00**	**0**
			ABS-06	0	4	50	50	0.016	**0E+00**	**0**
			ABS-07	0.00075	4	50	50	0.016	**2E-06**	**0.1**
			ABS-13	0	4	50	50	0.016	**0E+00**	**0**
		Forest, far	ABS-01	0	4	50	50	0.016	**0E+00**	**0**
			ABS-02	0	4	50	50	0.016	**0E+00**	**0**
			ABS-08	0	4	50	50	0.016	**0E+00**	**0**
			ABS-11	0.0010	4	50	50	0.016	**3E-06**	**0.2**
		Across all forest areas		0.00055	4	50	50	0.016	**2E-06**	**0.1**
	Campfire building/ burning	Forest, near	ABS-10	0.0050	2	50	50	0.0082	**7E-06**	**0.5**
			ABS-14	0	2	50	50	0.0082	**0E+00**	**0**
		Forest, intermed.	ABS-03	0.0026	2	50	50	0.0082	**4E-06**	**0.2**
			ABS-05	0.0030	2	50	50	0.0082	**4E-06**	**0.3**
			ABS-06	0.0025	2	50	50	0.0082	**4E-06**	**0.2**
			ABS-07	0.00075	2	50	50	0.0082	**1E-06**	**0.07**
			ABS-13	0.0026	2	50	50	0.0082	**4E-06**	**0.2**
		Forest, far	ABS-01	0.00085	2	50	50	0.0082	**1E-06**	**0.08**
			ABS-02	0.00085	2	50	50	0.0082	**1E-06**	**0.08**
			ABS-08	0	2	50	50	0.0082	**0E+00**	**0**
			ABS-11	0	2	50	50	0.0082	**0E+00**	**0**
		Across all forest areas		0.0016	2	50	50	0.0082	**2E-06**	**0.1**
	Driving	Forest, near	ABS-10	0.00027	3	50	50	0.012	**6E-07**	**0.04**
		Forest, intermed.	ABS-07	0	3	50	50	0.012	**0E+00**	**0**
		Forest, far	ABS-02	0	3	50	50	0.012	**0E+00**	**0**
		Across all forest areas		0.000090	3	50	50	0.012	**2E-07**	**0.01**
	Fishing/ boating	Kootenai River	KR	0	8	60	50	0.039	**0E+00**	**0**

APPENIDIX F

Estimated Risks from Exposures to LA During Disturbances of Soils in OU3 - Stratified by ABS Area

Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Location*	ABS Area	EPC	RME Exposure Parameters				Cancer Risk	Non-cancer HQ
				Mean Air Conc. (PCME LA s/cc)+	ET (hours/ day)	EF (days/ year)	ED (years)	TWF		
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	ABS-10	0	10	14	10	0.0023	**0E+00**	**0**
		Forest, intermed.	ABS-07	0.014	10	14	10	0.0023	**5E-06**	**0.3**
		Forest, far	ABS-02	0.0045	10	14	10	0.0023	**2E-06**	**0.1**
		Across all areas		0.0061	10	14	10	0.0023	**2E-06**	**0.2**
	Cutting firelines with heavy machinery	Forest, near	ABS-10	0.0021	10	14	10	0.0023	**8E-07**	**0.05**
		Forest, intermed.	ABS-07	0.0029	10	14	10	0.0023	**1E-06**	**0.07**
		Forest, far	ABS-02	0.0016	10	14	10	0.0023	**6E-07**	**0.04**
		Across all forest areas		0.0022	10	14	10	0.0023	**8E-07**	**0.06**

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

*Distances from the mine are defined as follows:

Forest, near: within two miles from the mine

Forest, intermed.: between two and six miles from the mine.

Forest, far: greater than or equal to six miles from the mine

Notes:

ABS - activity-based sampling
ATV - all terrain vehicle
Conc. - concentration
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RC - Rainy Creek
KR - Kootenai River
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX G
SITE-SPECIFIC EXPOSURE INFORMATION

G.1 – OU1 Search & Rescue Building
G.2 – OU5 Motocross Track
G.3 – OU5 Occupied Buildings

Appendix G-1
Exposure Questionnaire - OU1 Former Export Plant, Search and Rescue Volunteers
Libby Asbestos Superfund Site

			As Reported		Adjusted (a)		As Reported		Adjusted (a)		Calculated ET (hours/day)	
Individual #	**EF at OU1 (days/yr)**	Total ET at OU1 (hours/day)	Time Indoors (%)	Time Outdoors (%)	Time Indoors (%)	Time Outdoors (%)	% Indoor Time in Garage	% Indoor Time in Meeting Room	% Indoor Time in Garage	% Indoor Time in Meeting Room	**ET (outdoor)**	**ET (indoor)**
1	**45**	2	75%	25%	75%	25%	25%	75%	25%	75%	**0.50**	**1.50**
2	**60**	2	25%	60%	29%	71%	10%	20%	33%	67%	**1.41**	**0.59**
3	**35**	4	10%	90%	10%	90%	10%	90%	10%	90%	**3.60**	**0.40**
4	**104**	2	75%	25%	75%	25%	25%	75%	25%	75%	**0.50**	**1.50**
5	**50**	2	85%	15%	85%	15%	25%	75%	25%	75%	**0.30**	**1.70**
6	**100**	2	80%	20%	80%	20%	40%	60%	40%	60%	**0.40**	**1.60**
7	**25**	3	80%	20%	80%	20%	25%	70%	26%	74%	**0.60**	**2.40**
8	**35**	4	80%	20%	80%	20%	20%	80%	20%	80%	**0.80**	**3.20**
9	**20**	2	90%	10%	90%	10%	50%	50%	50%	50%	**0.20**	**1.80**
10	**42**	4	80%	20%	80%	20%	10%	90%	10%	90%	**0.80**	**3.20**
11	**30**	2	90%	10%	90%	10%	10%	80%	11%	89%	**0.20**	**1.80**
12	**120**	2	95%	5%	95%	5%	25%	75%	25%	75%	**0.10**	**1.90**
13	**104**	4	70%	30%	70%	30%	90%	10%	90%	10%	**1.20**	**2.80**
14	**60**	2	60%	40%	60%	40%	40%	60%	40%	60%	**0.80**	**1.20**
15	**100**	1	80%	20%	80%	20%	30%	70%	30%	70%	**0.20**	**0.80**
16	**30**	2	70%	30%	70%	30%	20%	80%	20%	80%	**0.60**	**1.40**
17	**300**	2	99%	1%	99%	1%	1%	99%	1%	99%	**0.02**	**1.98**
18	**36**	4	30%	70%	30%	70%	18%	65%	22%	78%	**2.80**	**1.20**

Summary Statistics

Statistic	**EF (days/year)**	**ET, indoor (hours/day)**
Mean	**72**	**1.7**
Stdev	65	0.8
Min	20	0.4
Max	300	3.2
95th %tile	**147**	**3.2**

Selected for use in the risk characterization

Notes:

NA = not available

a) Cells highlighted in blue are cases where the values on proportion of time spent in two location categories do not sum to 100% as expected. In these cases, the reported values were re-scaled to sum to 100% while maintaining the ratio of the values reported.

b) Three respondents did not indicate an expected age at stop. An age of 70 years was assumed in these cases. Stop ages reported as 90-100 years were assumed to be 80 years.

c) 5th percentile value rather than 95th percentile

APPENDIX G-2
OU5 MOTO-X PARK ACTIVITY SURVEY RESULTS

Participant	Reported Survey Results			Estimated Exposure Parameter Values†	
	d/yr @ track	hr/d @ track	hr/d riding	EF (d/yr)	ET* (hr/d)
1	21-30	3-4	1-2	**25**	**1.5**
2	31-50	1-2	1-2	**40**	**1.5**
3	21-30	3-4	1-2	**25**	**1.5**
4	31-50	3-4	1-2	**40**	**1.5**
5	21-30	1-2	0.5-0.9	**25**	**0.75**
6	21-30	3-4	3-4	**25**	**3.5**
			CTE (mean):	**30**	**2**
			RME (max):	**40**	**4**

† Based on midpoint of reported range

* Based on reported time spent riding

APPENDIX G-3
RESULTS OF ACTIVITY SURVEY FOR WORKERS IN CURRENTLY-OCCUPIED BUILDINGS IN OU5

Survey ID	Code	Building	ET (hr/d)	EF (d/yr)	% Active	Notes
22	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
23	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
24	CMB-B&C	CMB-B&C Packaging	7.00	180	100	
25	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
26	CMB-B&C	CMB-B&C Packaging	6.00	180	100	
1	CMB	CMB-A1	1.00	365	95	
15	CMB	CMB-Columbia Mechanical	3.00	240	90	
16	CMB	CMB-Columbia Mechanical	3.00	240	90	
18	CMB	CMB-Kootenai Insulation	1.00	96	100	
19	CMB	CMB-Kootenai Insulation	4.00	300	90	
17	CMB	CMB-RPO Stone	8.00	240	100	
20	CMB	CMB-RPO Stone	7.00	140	100	
5	CMB	CMB-TBC	1.00	100	100	
21	CMB	CMB-Thompson Contracting	5.00	15	100	
27	CMB	CMB-Thompson Contracting	1.00	60	100	
28	CMB	CMB-Thompson Contracting	0.50	60	100	
29	CMB	CMB-Thompson Contracting	1.00	150	40	
30	CMB	CMB-Thompson Contracting	1.00	60	50	
31	CMB	CMB-Thompson Contracting	10.00	30	50	
32	CMB	CMB-Thompson Contracting	2.00	4	90	
33	CMB	CMB-Thompson Contracting	1.00	320	50	
34	CMB	CMB-Thompson Contracting	1.00	60	100	
2	LEG	Luck EG Electrical Shed	0.17	300	100	
3	LEG	Luck EG Electrical Shed	0.17	240	100	
4	LEG	Luck EG Electrical Shed	0.33	300	100	
6		Luck EG Electrical Shed	0.08	2	100	Excluded
6	LEGO	Luck EG Office	6.00	220	50	
7	SH	Scale House	0.07	9	100	
8	SH	Scale House	0.07	10	100	
9	SH	Scale House	0.07	9	100	
10	SH	Scale House	0.07	8	100	
11	SH	Scale House	0.08	10	100	
12	SH	Scale House	0.08	9	100	
13	SH	Scale House	0.07	8	100	
14	SH	Scale House	0.05	10	100	
(a)	CDM Smith	Office - Type 1 worker	8.00	250	5	
(a)	CDM Smith	Office - Type 2 worker	4.00	280	5	
(a)	CDM Smith	Office - Type 3 worker	1.00	250	5	

(a) Based on info from CDM Smith on 9/17/08

OU5 INDOOR WORKER ACTIVITY SURVEY SUMMARY

Panel A: CTE (Based on mean values)

OU5 Building Location	N surveyed	% of Time Active	ET (hr/d)	EF (d/yr)
CMB - B&C Pkg	5	100	6.2	180
CMB - other	17	85	3.0	146
Luck EG Shed	3	100	0.22	280
Luck EG Office	1	50	6.0	220
Scale House	8	100	0.07	9
CDM Smith Office Type 1 (a)	10	5	8.0	250
CDM Smith Office Type 2 (a)	20	5	4.0	280
CDM Smith Office Type 3 (a)	30	5	1.0	250

Panel B: RME (Based on high-end values)

OU5 Building Location	N surveyed	% of Time Active	ET (hr/d)	EF (d/yr)
CMB - B&C Pkg	5	100	7.0	180
CMB - other	17	100	8.4	329
Luck EG Shed	3	100	0.33	300
Luck EG Office	1	--	--	--
Scale House	8	100	0.08	10
CDM Smith Office Type 1		80 (b)	8.0	250

(a) Mean statistics provided by CDM Smith; risk calculations are based on Type 1
(b) Assumed

CMB = Central Maintenance Building
ET = exposure time
EF = exposure frequency

APPENDIX H
UPPER-BOUND RISK CALCULATIONS

APPENDIX H-1

Estimated Risks from Exposure to LA in Ambient Air Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Exposure Media	Receptor Population	Exposure Location	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor air, under ambient conditions	Resident	OU4, Libby	0.0000062	0.000040	6.9	350	50	0.20	2E-07	1E-06	0.01	0.09
		Within community	0.0000048	0.000039	6.9	350	50	0.20	2E-07	1E-06	0.01	0.09
		Along transportation corridors	0.0000098	0.000043	6.9	350	50	0.20	3E-07	1E-06	0.02	0.09
		OU7, Troy	0.0000015	0.00067	6.9	350	50	0.20	5E-08	2E-05	0.003	1
	Recreational visitor	OU3, mine site	0.00020	0.000040	8	50	50	0.033	1E-06	2E-07	0.07	0.01

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-2
Estimated Risks from Exposure to LA During Disturbances of Residential Soils Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Panel A: Residential Exposures

Operable Unit	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/day)	EF (days/year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	**Yards (Mowing, Raking, Digging)**											
	Bin A	high intensity	0.0040	0.0062	0.3	60	50	0.0015	1E-06	2E-06	0.07	0.1
		typical intensity	0.00011	0.0014	6.3	60	50	0.031	6E-07	7E-06	0.04	0.5
								TOTAL	2E-06	9E-06	0.1	0.6
	Bin B1	high intensity	0.061	0.064	0.3	60	50	0.0015	2E-05	0	1	1
		typical intensity	0.0024	0.0036	6.3	60	50	0.031	1E-05	2E-05	0.8	1
								TOTAL	3E-05	3E-05	2	2
	Bin B2/C	high intensity	0.21	0.21	0.3	60	50	0.0015	5E-05	5E-05	3	3
		typical intensity	0.0080	0.0082	6.3	60	50	0.031	4E-05	4E-05	3	3
								TOTAL	9E-05	1E-04	6	6
	Gardens (Rototilling)											
	Bin B1	---	0.039	0.039	2	2	50	0.00033	2E-06	2E-06	0.1	0.1
	Gardens (Digging)											
	Bin A	---	0.00020	0.0016	3.3	40	50	0.011	4E-07	3E-06	0.02	0.2
	Bin B1	---	0.00066	0.0059	3.3	40	50	0.011	1E-06	1E-05	0.08	0.7
	Bin B2/C	---	0	0.0030	3.3	40	50	0.011	0E+00	5E-06	0	0.4
	Driveway (Playing & Digging)											
	Bin A	---	0	0.0039	2	225	15	0.011	0E+00	7E-06	0	0.5
	Bin B1	---	0.0057	0.0094	2	225	15	0.011	1E-05	2E-05	0.7	1
	Bin B2/C	---	0.0050	0.0036	2	225	15	0.011	9E-06	7E-06	0.6	0.4
	LUAs (ATV-riding)											
	Bin A	---	0.0012	0.0026	2	20	50	0.0033	7E-07	1E-06	0.04	0.09
	Bin B1	---	0.0014	0.0024	2	20	50	0.0033	8E-07	1E-06	0.05	0.09
OU7	**Yards (Mowing, Raking, Digging)**											
	Bin A	typical intensity	0.000062	0.00025	6.6	60	50	0.032	3E-07	1E-06	0.02	0.09
	Bin B1	typical intensity	0	0.00022	6.6	60	50	0.032	0E+00	1E-06	0	0.08
	Residential, Outdoor Gardens (Digging & Rototilling)[++]											
	Bin A	---	0.000023	0.00023	5.3	42	50	0.018	7E-08	7E-07	0.005	0.05
	Bin B1	---	0	0.00022	5.3	42	50	0.018	0E+00	7E-07	0	0.04
	Residential, Outdoor Driveway (Playing & Digging)											
	Bin A	---	0.000079	0.00028	2	225	15	0.011	1E-07	5E-07	0.01	0.03
	Bin B1	---	0.000085	0.00021	2	225	15	0.011	2E-07	4E-07	0.01	0.03

Panel B: Outdoor Worker Exposures

Operable Unit	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/day)	EF (days/year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	**Yards (Mowing, Raking, Digging)**											
	Bin A	high intensity	0.0040	0.0062	0.4	100	25	0.0016	1E-06	2E-06	0.07	0.1
		typical intensity	0.00011	0.0014	7.6	100	25	0.031	6E-07	7E-06	0.04	0.5
								TOTAL	2E-06	9E-06	0.1	0.6
	Bin B1	high intensity	0.061	0.064	0.4	100	25	0.0016	2E-05	2E-05	1	1
		typical intensity	0.0024	0.0036	7.6	100	25	0.031	1E-05	2E-05	0.8	1
								TOTAL	3E-05	4E-05	2	2
	Bin B2/C	high intensity	0.21	0.21	0.4	100	25	0.0016	6E-05	6E-05	4	4
		typical intensity	0.0080	0.0082	7.6	100	25	0.031	4E-05	4E-05	3	3
								TOTAL	1E-04	1E-04	7	7
	Gardens (Rototilling)											
	Bin B1	---	0.039	0.039	4	100	25	0.016	1E-04	1E-04	7	7
	Gardens (Digging)											
	Bin A	---	0.00020	0.0016	4	100	25	0.016	6E-07	5E-06	0.04	0.3
	Bin B1	---	0.00066	0.0059	4	100	25	0.016	2E-06	2E-05	0.1	1
	Bin B2/C	---	0	0.0030	4	100	25	0.016	0E+00	8E-06	0	0.5
OU7	**Yards (Mowing, Raking, Digging)**											
	Bin A	typical intensity	0.000062	0.00025	8	100	25	0.033	3E-07	1E-06	0.02	0.09
	Bin B1	typical intensity	0	0.00022	8	100	25	0.033	0E+00	1E-06	0	0.08
	Residential, Outdoor Gardens (Digging & Rototilling)[+++]											
	Bin A	---	0.000023	0.00023	4	100	25	0.016	6E-08	6E-07	0.004	0.04
	Bin B1	---	0	0.00022	4	100	25	0.016	0E+00	6E-07	0	0.04

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)
[++] Exposure time and frequency have been summed because the EPC is based on a combination of the activities.
[+++] Exposure time has been summed because the EPC is based on a combination of the activities.
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.
[1] PLM-VE Bin:
A - ND
B1 - Tr
B2 - <1%
C - ≥ 1%

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-2

Estimated Risks from Exposure to LA During Disturbances of Residential Soils Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Panel B: Outdoor Worker Exposures

Operable Unit	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/day)	EF (days/year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	**Yards (Mowing, Raking, Digging)**											
	Bin A	**high intensity**	0.0040	0.0062	0.4	100	25	0.002	1E-06	2E-06	0.07	0.1
		typical intensity	0.00011	0.0014	7.6	100	25	0.031	6E-07	7E-06	0.04	0.5
								TOTAL	2E-06	9E-06	0.1	0.6
	Bin B1	**high intensity**	0.061	0.064	0.4	100	25	0.002	2E-05	2E-05	1	1
		typical intensity	0.0024	0.0036	7.6	100	25	0.031	1E-05	2E-05	0.8	1
								TOTAL	3E-05	4E-05	2	2
	Bin B2/C	**high intensity**	0.21	0.21	0.4	100	25	0.002	6E-05	6E-05	4	4
		typical intensity	0.0080	0.00820	7.6	100	25	0.031	4E-05	4E-05	3	3
								TOTAL	1E-04	1E-04	7	7
	Gardens (Rototilling)											
	Bin B1	---	0.039	0.039	4	100	25	0.016	1E-04	1E-04	7	7
	Gardens (Digging)											
	Bin A	---	0.00020	0.0016	4	100	25	0.016	6E-07	5E-06	0.04	0.3
	Bin B1	---	0.00066	0.0059	4	100	25	0.016	2E-06	2E-05	0.1	1
	Bin B2/C	---	0	0.0030	4	100	25	0.016	0E+00	8E-06	0	0.5
OU7	**Yards (Mowing, Raking, Digging)**											
	Bin A	**typical intensity**	0.000062	0.00025	8	100	25	0.033	3E-07	1E-06	0.02	0.09
	Bin B1	**typical intensity**	0	0.00022	8	100	25	0.033	0E+00	1E-06	0	0.08
	Residential, Outdoor Gardens (Digging & Rototilling)											
	Bin A	---	0.000023	0.00023	4	100	25	0.016	6E-08	6E-07	0.004	0.04
	Bin B1	---	0	0.00022	4	100	25	0.016	0E+00	6E-07	0	0.04

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

[1] PLM-VE Bin:

A - ND

B1 - Tr

B2 - <1%

C - ≥ 1%

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
PLM-VE - polarized light microscopy - visual area estimation
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-3

Estimated Risks from Exposure to LA During Disturbances of Residential Soils Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Receptor Type	Exposure Scenario & Soil Condition[1]	Yard ABS Script Intensity	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
				Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)++	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4/OU7	Outdoor Worker	Bin A	digging, high intensity	0.0053	0.0094	2	32.5	25	0.0027	2E-06	4E-06	0.2	0.3
		Bin B1	digging, high intensity	0.16	0.16	2	7.5	25	0.00061	2E-05	2E-05	1	1
		Bin B2/C	digging, high intensity	0.52	0.52	2	10	25	0.00082	7E-05	7E-05	5	5
									TOTAL	**9E-05**	**9E-05**	6	6
	Resident	Bin A	digging, high intensity	0.0053	0.0094	2	1	50	0.00016	0	0	0.01	0.02
		Bin B1	digging, high intensity	0.16	0.16	2	1	50	0.00016	4E-06	4E-06	0.3	0.3
		Bin B2/C	digging, high intensity	0.52	0.52	2	1	50	0.00016	1E-05	1E-05	0.9	0.9

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

++ The total exposure frequency for the worker has been allocated to the various soil conditions according to the assumed frequency each condition is expected to be encountered.

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

[1] PLM-VE Bin:

A - ND

B1 - Tr

B2 - <1%

C - ≥ 1%

Notes:

ABS - activity-based sampling

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

OU - operable unit

PCME - phase contrast microscopy - equivalent

PLM-VE - polarized light microscopy - visual area estimation

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

APPENDIX H-4

Estimated Risks from Exposure to LA During Disturbances of Soils at Schools and Parks Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Exposure Location	Receptor Type	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	Kootenai Valley Head Start	Student	0	0.0018	0.5	128	2	0.00021	0E+00	6E-08	0	0.004
		Maintenance Worker	0	0.0025	1.0	128	25	0.0052	0E+00	2E-06	0	0.1
		Lawn Mower	0.00074	0.0039	10	22	25	0.0090	1E-06	6E-06	0.07	0.4
	Libby Elementary School	Student	0.0019	0.0031	2.0	180	6	0.0035	1E-06	2E-06	0.07	0.1
		Maintenance Worker	0	0.0020	1.5	260	25	0.016	0E+00	5E-06	0	0.3
		Lawn Mower	0	0.0028	10	22	25	0.0090	0E+00	4E-06	0	0.3
	Libby Middle School	Student	0.0020	0.0027	1.6	90	3	0.00070	2E-07	3E-07	0.02	0.02
		Maintenance Worker	0	0.0019	0.5	260	25	0.0053	0E+00	2E-06	0	0.1
		Lawn Mower	0	0.0061	10	22	25	0.0090	0E+00	9E-06	0	0.6
	Libby High School	Student	0.00017	0.0054	0.67	45	4	0.00020	6E-09	2E-07	0.0004	0.01
		Maintenance Worker	0	0.0026	1.0	260	25	0.011	0E+00	5E-06	0	0.3
		Lawn Mower	0	0.0023	10	22	25	0.0090	0E+00	3E-06	0	0.2
	Libby Admin. Building	Student	0	0.00022	0.75	180	6	0.0013	0E+00	5E-08	0	0.003
		Maintenance Worker	0	0.00027	1.5	260	25	0.016	0E+00	7E-07	0	0.05
		Lawn Mower	0.000019	0.00022	10	22	25	0.0090	3E-08	3E-07	0.002	0.02
	Libby High School and Libby Admin Building	Power Sweeper	0	0.0021	2.0	22	25	0.0018	0E+00	7E-07	0	0.04
	Cabinet View Country Club	Maintenance Worker	0.00056	0.00096	8.0	100	15	0.020	2E-06	3E-06	0.1	0.2
OU7	Morrison Elementary School	Student	0	0.00022	2.0	180	6	0.0035	0E+00	1E-07	0	0.009
	Timberbeast Golf Course	Recreational Visitor, adult	0	0.00022	5.0	48	50	0.020	0E+00	7E-07	0	0.05
	Roosevelt Park, ball fields	Recreational Visitor, adult	0.00011	0.00022	5.0	48	50	0.020	4E-07	7E-07	0.02	0.05
	Roosevelt Park, playground	Recreational Visitor, child	0	0.00022	10.7	48	10	0.0084	0E+00	3E-07	0	0.02

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

OU - operable unit

PCME - phase contrast microscopy - equivalent

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

APPENDIX H-5

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils on Bike Paths and Trails Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Sector	Receptor Type	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU4	Sector A-C	Adult Rider	0	0.0034	2	90	50	0.015	0E+00	8E-06	0	0.6
		Inside Trailer	0	0.0086	2	90	5	0.0015	0E+00	2E-06	0	0.1
OU7	---	Adult Rider	0	0.00022	0.75	90	50	0.0055	0E+00	2E-07	0	0.01
		Inside Trailer	0.000011	0.00022	0.75	90	5	0.00055	1E-09	2E-08	0.00007	0.001

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-6

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU1 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor Worker	Mowing	0.00044	0.0028	6	13	25	0.0032	2E-07	1.E-06	0.02	0.1
	Weed-trimming	0	0.011	1	13	25	0.00053	0E+00	1.E-06	0	0.07

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
s/cc - structures per cubic centimeter
RME - reasonable maximum exposure
TWF - time-weighting factor

APPENDIX H-7

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU2 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor	Exposure Scenario	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor Worker	Mowing Hwy 37 ROW	0	0.018	1	5	15	0.00012	0E+00	4E-07	0	0.02
Recreational Visitor	Hiking along Kootenai River	0	0.0048	2	10	50	0.0016	0E+00	1E-06	0	0.09

[+] Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-8

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU3 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor Type	Exposure Scenario	Exposure Area*	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Recreational Visitor	Hiking	Rainy Creek	0.0093	0.011	6	48	50	0.023	4E-05	4E-05	2	3
		Forest, near	0.00050	0.0042	8	50	50	0.033	3E-06	2E-05	0.2	2
		Forest, intermed.	0.00065	0.0056	8	50	50	0.033	4E-06	3E-05	0.2	2
		Forest, far	0.00023	0.0052	8	50	50	0.033	1E-06	3E-05	0.08	2
	ATV-riding	Forest, near	0.0014	0.0065	4	50	50	0.016	4E-06	2E-05	0.3	1
		Forest, intermed.	0.00050	0.0062	4	50	50	0.016	1E-06	0	0	1
		Forest, far	0.00022	0.0060	4	50	50	0.016	6E-07	2E-05	0.04	1
	Campfire building/burning	Forest, near	0.0023	0.0069	2	50	50	0.0082	3E-06	1E-05	0.2	0.6
		Forest, intermed.	0.0023	0.0065	2	50	50	0.0082	3E-06	9E-06	0.2	0.6
		Forest, far	0.00046	0.0060	2	50	50	0.0082	6E-07	8E-06	0.04	0.5
	Driving	Forest, near	0.00027	0.025	3	50	50	0.012	6E-07	5E-05	0.04	3
		Forest, intermed.	0	0.025	3	50	50	0.012	0E+00	5E-05	0	3
		Forest, far	0	0.024	3	50	50	0.012	0E+00	5E-05	0	3
	Fishing/boating	Kootenai River	0	0.00031	8	60	50	0.039	0E+00	2E-06	0	0.1
Outdoor Worker (Firefighter)	Cutting firelines by hand	Forest, near	0	0.0083	10	14	10	0.0023	0E+00	3E-06	0	0.2
		Forest, intermed.	0.014	0.017	10	14	10	0.0023	5E-06	7E-06	0.3	0.4
		Forest, far	0.0045	0.0092	10	14	10	0.0023	2E-06	4E-06	0.1	0.2
		Forest, NPL boundary	0.00017	0.0011	10	14	10	0.0023	7E-08	4E-07	0.004	0.03
	Cutting firelines with heavy machinery	Forest, near	0.0021	0.0074	10	14	10	0.0023	8E-07	3E-06	0.05	0.2
		Forest, intermed.	0.0029	0.0064	10	14	10	0.0023	1E-06	2E-06	0.07	0.2
		Forest, far	0.0016	0.011	10	14	10	0.0023	6E-07	4E-06	0.04	0.3

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

*Distances from the mine are defined as follows:
Forest, near: within two miles from the mine
Forest, intermed.: between two and six miles from the mine
Forest, far: greater than or equal to six miles from the mine
Forest, NPL boundary: locations along the NPL boundary evaluated in the nature & extent forest study (see Section 6.6.2.4)

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
NPL - National Priorities List
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-9

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU5 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor Type	Exposure Location	Exposure Type	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Recreational Visitor	MotoX Track	Participant	0	0.0098	4	40	55	0.014	0E+00	2E-05	0	2
		Spectator	0	0.0011	4	60	45	0.018	0E+00	3E-06	0	0.2
	Bike Path	Rider, adult	0.000038	0.00091	2	48	50	0.0078	5E-08	1E-06	0.003	0.08
		Trailer, child	0.000053	0.00098	2	48	5	0.00078	7E-09	1E-07	0.0005	0.009
Outdoor Worker	Area 1	Worker	0.00080	0.011	4	135	25	0.022	3E-06	4E-05	0.2	3
	Area 2	Worker	0.00091	0.0040	4	135	25	0.022	3E-06	2E-05	0.2	1
	Area 3	Worker	0.0025	0.0036	4	135	25	0.022	9E-06	1E-05	0.6	0.9
	Area 4	Worker	0	0.0043	4	135	25	0.022	0E+00	2E-05	0	1
	Area 5	Worker	0.0057	0.017	4	135	25	0.022	2E-05	7E-05	1	4
	Area 6	Worker	0.0010	0.0035	4	135	25	0.022	4E-06	1E-05	0.2	0.9
	Area 7	Worker	0.00071	0.0027	4	135	25	0.022	3E-06	1E-05	0.2	0.7
	Area 8	Worker	0.0013	0.0025	4	135	25	0.022	5E-06	9E-06	0.3	0.6

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-10

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU6 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Operable Unit	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
OU6	Pedestrian tresspasser	0	0.00065	4	60	50	0.020	0E+00	2E-06	0	0.1
	On-looker	0	0.0010	2	60	15	0.0029	0E+00	5E-07	0	0.03
	BNSF worker	0	0.00034	8	60	50	0.039	0E+00	2E-06	0	0.1

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling

BNSF - Burlington Northern Santa Fe

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

OU - operable unit

PCME - phase contrast microscopy - equivalent

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

APPENDIX H-11

ABS Air Summary Statistics and Estimated Risks from Exposures to LA During Disturbances of Soils in OU8 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Receptor	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-Cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Recreational	ATV riding ROW	0.00018	0.0029	4	184	30	0.036	1E-06	2E-05	0.07	1
Outdoor Worker	Brush-hogging ROW	0.0036	0.0055	8	60	30	0.023	1E-05	2E-05	0.9	1
	Rotomilling	0.000049	0.0036	8	60	30	0.023	2E-07	1E-05	0.01	0.9
Various	Driving on Libby roads	0	0.00065	2	225	50	0.037	0E+00	4E-06	0	0.3
	Driving on Troy roads	0.00033	0.00047	0.75	225	50	0.014	8E-07	1E-06	0.05	0.07

+ Concentrations have been adjusted to account for filter preparation method (see Section 2.3.4)

* Original number of samples was 62 but sample number HW-00890 was overloaded

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ATV - all-terrain vehicle
ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
ROW - right-of-way
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-12
Estimated Risks from Exposure to LA from Indoor Air in OU4 and OU7 Based on Upper-Bound Concentrations
Libby Asbestos Superfund Site

Receptor Type	Building Description	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
			Mean [a]	Estimated Upper-Bound [b]	ET (hours/day)	EF (days/year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Resident	OU4 Residential Properties - "Pre-Removal"	Active Behaviors	0.00099	0.016	5.8	350	50	0.17	3E-05	5E-04	2	30
		Passive Behaviors	0.000068	0.00024	16.9	350	50	0.48	6E-06	2E-05	0.4	1
								Total:	3E-05	5E-04	2	30
	OU4 Residential Properties - "Post-Removal"	Active Behaviors	0.00018	0.00038	5.8	350	50	0.17	5E-06	1E-05	0.3	0.7
		Passive Behaviors	0.000032	0.00020	16.9	350	50	0.48	3E-06	2E-05	0.2	1
								Total:	8E-06	0	1	2
	OU4 Residential Properties - "No Removal"	Active Behaviors	0.000095	0.00049	5.8	350	50	0.17	3E-06	1E-05	0.2	0.9
		Passive Behaviors	0.000038	0.00021	16.9	350	50	0.48	3E-06	2E-05	0.2	1
								Total:	6E-06	3E-05	0.4	2
Indoor Worker	OU4 Commercial Properties - "Pre-Removal"	Active Behaviors	0.0033	0.0076	4	250	25	0.041	2E-05	5E-05	2	3
		Passive Behaviors	0.00027	0.00040	4	250	25	0.041	2E-06	3E-06	0.1	0.2
								Total:	2E-05	6E-05	2	3
	OU4 Commercial Properties - "Post-Removal"	Active Behaviors	0.00013	0.00015	4	250	25	0.041	9E-07	1E-06	0.06	0.07
		Passive Behaviors	0.0000096	0.000060	4	250	25	0.041	7E-08	4E-07	0.004	0.03
								Total:	1E-06	1E-06	0.06	0.1
	OU4 Commercial Properties - "No Removal"	Active Behaviors	0.00021	0.00059	4	250	25	0.041	1E-06	4E-06	0.09	0.3
		Passive Behaviors	0.000039	0.00028	4	250	25	0.041	3E-07	2E-06	0.02	0.1
								Total:	2E-06	6E-06	0.1	0.4
Resident	OU7 Residential Properties - "Post-Removal"	Active Behaviors	0.000027	0.000058	5.8	350	50	0.17	8E-07	2E-06	0.05	0.1
		Passive Behaviors	0.000013	0.000027	16.9	350	50	0.48	1E-06	2E-06	0.07	0.1
								Total:	2E-06	4E-06	0.1	0.2
	OU7 Residential Properties - "No Removal"	Active Behaviors	0.000056	0.000079	5.8	350	50	0.17	2E-06	2E-06	0.1	0.1
		Passive Behaviors	0.000016	0.000026	16.9	350	50	0.48	1E-06	2E-06	0.08	0.1
								Total:	3E-06	4E-06	0.2	0.2
Indoor Worker	OU7 Residential Properties - "No Removal"	Active Behaviors	0.000046	0.000068	4	250	25	0.041	3E-07	5E-07	0.02	0.03
		Passive Behaviors	0.0000048	0.000019	4	250	25	0.041	3E-08	1E-07	0.002	0.009
								Total:	4E-07	6E-07	0.02	0.04
Tradesperson, worker	OU4 Residential/Commerical - "Pre-Removal"	Bulk VI Removal	0.044	0.044	4	250	25	0.041	3E-04	3E-04	20	20
		Demolition	0.0078	0.0078	4	250	25	0.041	5E-05	5E-05	4	4
		Detailing attic	0.025	0.025	4	250	25	0.041	2E-04	2E-04	20	20
		Wet wipe/HEPA vac	0.015	0.015	4	250	25	0.041	1E-04	1E-04	7	7
Student	Kootenai Valley Head Start	Typical behaviors	0	0.00057	7	200	2	0.0046	0E+00	4E-07	0	0.03
	Libby Elementary School	Typical behaviors	0.000059	0.00056	7	200	6	0.014	1E-07	1E-06	0.009	0.08
	Libby Middle School	Typical behaviors	0.000051	0.00056	7	200	3	0.0068	6E-08	6E-07	0.004	0.04
	Libby High School	Typical behaviors	0	0.00054	7	200	4	0.0091	0E+00	8E-07	0	0.05
	Libby Admin. Building	Typical behaviors	0	0.00058	7	200	6	0.014	0E+00	1E-06	0	0.09
Teacher	Kootenai Valley Head Start	Typical behaviors	0	0.00057	8	210	25	0.068	0E+00	7E-06	0	0.4
	Libby Elementary School	Typical behaviors	0.000059	0.00056	8	210	25	0.068	7E-07	6E-06	0.05	0.4
	Libby Middle School	Typical behaviors	0.000051	0.00056	8	210	25	0.068	6E-07	6E-06	0.04	0.4
	Libby High School	Typical behaviors	0	0.00054	8	210	25	0.068	0E+00	6E-06	0	0.4
	Libby Admin. Building	Typical behaviors	0	0.00058	8	210	25	0.068	0E+00	7E-06	0	0.4

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)
[a] Non-detect samples are evaluated at zero.
[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-13

Estimated Risks from Exposure to LA from Indoor Air in OU1 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Building Description	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Office	Active (high-end)	0.00033	0.00033	3.2	147	50	0.038	2E-06	2E-06	0.1	0.1
Garage	Active (high-end)	0.00022	0.00022	3.2	147	50	0.038	1E-06	1E-06	0.09	0.09

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-14

Estimated Risks from Exposure to LA from Indoor Air in OU5 Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Building Description	Exposure Scenario	EPC (PCME LA s/cc)+		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Occupied Buildings											
B+C Packaging	Active Behaviors	0.000094	0.0058	1	300	5	0.0024	4E-08	2E-06	0.003	0.2
	Passive Behaviors	0	0.00049	*100% of time assumed to be active for RME*							
Bioreactor Building	Active Behaviors	0.00023	0.00061	6.4	250	25	0.065	3E-06	7E-06	0.2	0.4
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
CDM Smith Main Office	Active Behaviors	0.0013	0.0032	6.4	250	25	0.065	1E-05	4E-05	1	2
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
Central Maintenance Building	Active Behaviors	0.0010	0.013	8	319	27	0.11	2E-05	2E-04	1	20
	Passive Behaviors	0.00021	0.00021	*100% of time assumed to be active for RME*							
Fire Hall	Active Behaviors	0	0.0059	6.4	250	25	0.065	0E+00	7E-05	0	4
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
Log Yard Truck Scale House	Active Behaviors	0.0065	0.050	0.083	10	25	0.000034	4E-08	3E-07	0.002	0.02
	Passive Behaviors	0	0.00050	*100% of time assumed to be active for RME*							
Luck EG Electric Motor Shed	Active Behaviors	0.0025	0.0025	0.33	300	15	0.0024	1E-06	1E-06	0.07	0.07
	Passive Behaviors	0	0.00045	*100% of time assumed to be active for RME*							
Office/Laboratory	Active Behaviors	0.00025	0.00084	6.4	250	25	0.065	3E-06	9E-06	0.2	0.6
	Passive Behaviors	0	0.00049	1.6	250	25	0.016	0E+00	1E-06	0	0.09
Vacant Buildings											
Chemical Storage Building	Active (high-end)	0	0.00049	8	250	25	0.082	0E+00	7E-06	0	0.4
Diesel Fire Pump House	Active (high-end)	0.00011	0.00066	8	250	25	0.082	2E-06	9E-06	0.1	0.6
Electric Pump House	Active (high-end)	0.00034	0.0016	8	250	25	0.082	5E-06	2E-05	0.3	1
Intermediate Injection Building	Active (high-end)	0	0.00048	8	250	25	0.082	0E+00	7E-06	0	0.4
LTU Leachate Building #1	Active (high-end)	0.000039	0.00043	8	250	25	0.082	5E-07	6E-06	0.04	0.4
LTU Leachate Building #2	Active (high-end)	0	0.00049	8	250	25	0.082	0E+00	7E-06	0	0.4
Pipe Shop	Active (high-end)	0	0.0022	8	250	25	0.082	0E+00	3E-05	0	2
Power house/office	Active (high-end)	0	0.00091	8	250	25	0.082	0E+00	1E-05	0	0.8
Shed 12	Active (high-end)	0	0.00039	8	250	25	0.082	0E+00	5E-06	0	0.4
Tank Farm Building	Active (high-end)	0	0.00049	8	250	25	0.082	0E+00	7E-06	0	0.4

+ Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ED - exposure duration
EF - exposure frequency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
OU - operable unit
LA - Libby amphibole asbestos
PCME - phase contrast microscopy - equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor

APPENDIX H-15

Estimated Risks from Exposure to LA During Disturbances of Wood-Related Materials Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

Exposure Media	Receptor Population	Exposure/Disturbance Description	Wood Source*	EPC (PCME LA s/cc)[+]		RME Exposure Parameters				Cancer Risk		Non-cancer HQ	
				Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
Outdoor air, during bark disturbances	Resident	Wood harvesting (Felling trees, de-limbing, cutting, stacking firewood)	Forest, near	0.00014	0.0080	10	15	40	0.0098	2E-07	1E-05	0.02	0.9
			Forest, intermed.	0.0020	0.0058	10	15	40	0.0098	3E-06	1E-05	0.2	0.6
			Forest, far	0.00014	0.011	10	15	40	0.0098	2E-07	2E-05	0.01	1
	Outdoor Worker (commercial logger)	Hand-felling trees	~1 mile from mine	0.0034	0.0034	8	24	6	0.0019	1E-06	1E-06	0.07	0.07
		Hooking/skidding, processing timber	~1 mile from mine	0.088	0.088	10	24	12	0.0047	7E-05	7E-05	5	5
		Site restoration	~1 mile from mine	0.032	0.032	10	24	12	0.0047	0	0	2	2
		Simulated milling (chipping)	~1 mile from mine	0.0068	0.0068	10	24	12	0.0047	5E-06	5E-06	0.4	0.4
		Hand Felling	~4 miles from mine	0.0022	0.0065	8	24	6	0.0019	7E-07	2E-06	0.05	0.1
		Skidding/Hooking	~4 miles from mine	0.00065	0.0054	10	24	12	0.0047	5E-07	4E-06	0.03	0.3
		Mechanical Processing	~4 miles from mine	0	0.0064	10	24	12	0.0047	0E+00	5E-06	0	0.3
		Cutting slabs (pre-milling)	~4 miles from mine	0	0.0063	10	24	12	0.0047	0E+00	5E-06	0	0.3
		Simulated milling (chipping)	~4 miles from mine	0	0.0062	10	24	12	0.0047	0E+00	5E-06	0	0.3
		Site Restoration	~4 miles from mine	0.0040	0.0072	10	24	12	0.0047	3E-06	6E-06	0.2	0.4
	Outdoor Worker (at landfill)	Chipping wood waste piles	various	0	0.0021	4	135	25	0.022	0E+00	8E-06	0	0.5
	Outdoor Worker (USFS worker)	Forest management (Road maintenance, tree thinning, forest surveying)	Forest, near	0	0.013	8	30	10	0.0039	0E+00	9E-06	0	0.6
			Forest, intermed.	0.00064	0.011	8	30	10	0.0039	4E-07	8E-06	0.03	0.5
			Forest, far	0.00020	0.013	8	30	10	0.0039	1E-07	9E-06	0.009	0.6
Outdoor air, during woodchip/ mulch disturbances	Outdoor Worker (at OU5)	Woodchip/waste bark pile disturbances	various	0	0.0012	4	135	25	0.022	0E+00	5E-06	0	0.3
	Resident	Woodchip/mulch disturbances during gardening	various	0	0.00060	2	40	50	0.0065	0E+00	7E-07	0	0.04
Indoor Air, during wood-derived ash disturbances	Resident	Emptying woodstove ash after burning firewood	~1 mile from mine	0.14	0.14	0.25	48	50	0.0010	2E-05	2E-05	1	1
			Flower Creek	0.0074	0.0074	0.25	48	50	0.0010	1E-06	1E-06	0.08	0.08
			Bear Breek	0.0029	0.014	0.25	48	50	0.0010	5E-07	2E-06	0.03	0.2
Outdoor air, during bark disturbances in authentic wildfire	Resident	Downwind stations during wildfire	Souse Gulch	0	0.00070	24	5	50	0.0098	0E+00	1E-06	0	0.08
	Outdoor Worker (firefighter)	Ground-based firefighter activities	Souse Gulch	0.00031	0.0018	15	14	25	0.0086	5E-07	3E-06	0.03	0.2
		Air-based wildfire suppression**	Souse Gulch	0	0.0024	15	14	25	0.0086	0E+00	3E-06	0	0.2

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

[+] Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

*Distances from the mine are defined as follows:

Forest, near: within two miles from the mine

Forest, intermed.: between two and six miles from the mine.

Forest, far: greater than or equal to six miles from the mine

Flower Creek: approximately six miles from the mine

Bear Breek: approximately 10 miles from the mine

**Monitor was placed in the cockpit of the responding helicopter

Notes:

ED - exposure duration

EF - exposure frequency

EPC - exposure point concentration

ET - exposure time

HQ - hazard quotient

LA - Libby amphibole asbestos

OU - operable unit

PCME - phase contrast microscopy - equivalent

RME - reasonable maximum exposure

s/cc - structures per cubic centimeter

TWF - time-weighting factor

USFS - United States Forest Service

APPENDIX H-16

Estimated Risks from Exposure to LA During Background Soil Disturbances Based on Upper-Bound Concentrations

Libby Asbestos Superfund Site

ABS Script	ABS Dataset*	EPC (PCME LA s/cc)[+]		RME Exposure Parameters[++]				Cancer Risk		Non-cancer HQ	
		Mean [a]	Estimated Upper-Bound [b]	ET (hours/ day)	EF (days/ year)	ED (years)	TWF	Mean	Upper-Bound	Mean	Upper-Bound
"Bucket of dirt" digging	OU4 Background Areas	0.0016	0.0019	6.6	60	50	0.032	9E-06	1E-05	0.6	0.7
	OU7 Background Areas	0.00032	0.00058	6.6	60	50	0.032	2E-06	3E-06	0.1	0.2
	OU4 Topsoil Borrow Sources	0.000046	0.00013	6.6	60	50	0.032	3E-07	7E-07	0.02	0.05
Raking, mowing, digging	OU4 "Curb-to-Curb" Yards	0.00039	0.00055	6.6	60	50	0.032	2E-06	3E-06	0.1	0.2

* See the *Background Soil Summary Report* (EPA 2014) for a detailed discussion of each type of ABS dataset.

[+] Concentrations have been adjusted to account for preparation method (see Section 2.3.4)

[++] Exposure parameters for the RME residential yard soil disturbance scenario are used in the risk estimates.

[a] Non-detect samples are evaluated at zero.

[b] Non-detect samples are evaluated at the achieved sensitivity.

Notes:

ABS - activity-based sampling
ED - exposure duration
EF - exposure frequency
EPA - Environmental Protection Agency
EPC - exposure point concentration
ET - exposure time
HQ - hazard quotient
LA - Libby amphibole asbestos
OU - operable unit
PCME - phase contrast microscopy-equivalent
RME - reasonable maximum exposure
s/cc - structures per cubic centimeter
TWF - time-weighting factor